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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE  
Public Health Service

# INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
$10^{12}$	tera	T	tēr' a
$10^9$	giga	G	jī' ga
$10^6$	mega	M	mēg' a
$10^3$	kilo	k	kīl' o
$10^2$	hecto	h	hēk' to
$10^1$	deka	da	dēk' a
$10^{-1}$	deci	d	dēs' i
$10^{-2}$	centi	c	sēn' ti
$10^{-3}$	milli	m	mīl' i
$10^{-6}$	micro	μ	mī' kro
$10^{-9}$	nano	n	nān' o
$10^{-12}$	pico	p	pē' o
$10^{-15}$	femto	f	fēm' to

# SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV.....	billion electron volts.....	GeV
Ci.....	curie.....	$3.7 \times 10^{10}$ dps
cm.....	centimeter(s).....	0.394 inch
cpm.....	counts per minute.....	
dpm.....	disintegrations per minute.....	
dps.....	disintegrations per second.....	
eV.....	electron volt.....	$1.6 \times 10^{-12}$ ergs
g.....	gram(s).....	
GeV.....	giga electron volts.....	$1.6 \times 10^{-2}$ ergs
kg.....	kilogram(s).....	1,000 g = 2.205 lb
km <sup>2</sup> .....	square kilometer(s).....	
kVp.....	kilovolt peak.....	
m <sup>3</sup> .....	cubic meter(s).....	
mA.....	milliampere(s).....	
mCi/mi <sup>2</sup> .....	millicuries per square mile.....	0.386 nCi/m <sup>2</sup> (mCi/km <sup>2</sup> )
MeV.....	million (mega) electron volts.....	$1.6 \times 10^{-6}$ ergs
mg.....	milligram(s).....	
mi <sup>2</sup> .....	square mile(s).....	
ml.....	milliliter(s).....	
mm.....	millimeter(s).....	
nCi/m <sup>2</sup> .....	nanocuries per square meter.....	2.59 mCi/mi <sup>2</sup>
pCi.....	picocurie(s).....	$10^{-12}$ curie = 2.22 dpm
R.....	roentgen.....	
rad.....	unit of absorbed radiation dose.....	100 ergs/g





# RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 2, February 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

*Radiological Health Data and Reports*, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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## Comparison Of Environmental Radioactivity Levels After Foreign Nuclear Weapons Tests of May 9, 1966, and December 27, 1966

David R. Snavely and Warren A. Brill<sup>1</sup>

The environmental radioactivity levels following foreign nuclear weapons tests of May 9, 1966 and December 27, 1966 are compared, and the influence of dairy practices and weather conditions on levels of iodine-131 in milk are discussed. After the former test, the highest monthly deposition by precipitation occurred in the mid-section of the United States south of the Great Lakes (576 nCi/m<sup>2</sup> at Jefferson City, Mo.), and in the northeastern section of Florida. The highest monthly deposition after the latter test occurred along the northern section of the west coast (2,545 nCi/m<sup>2</sup> at Portland, Ore.), northern Utah, the area west of Lake Michigan and in northern Vermont. Following the December test, the highest gross beta radioactivity of surface air particulates (119 pCi/m<sup>3</sup> at Las Vegas, Nev.), the highest gross beta deposition by precipitation, and the highest contribution of nuclides belonging to volatile decay chains (including iodine-131), were found. The highest estimated cumulative iodine-131 intake from drinking 1 liter of milk per day (9,300 pCi/liter) occurred after the May test. This appeared to result from different dairying practices being used at the time of the two tests, and the more rapid elimination of iodine-131 from the cows' feed after the December test.

Two foreign nuclear weapons tests employing fission devices with yields estimated at a few hundred kilotons of TNT were conducted on May 9, 1966 and December 27, 1966, respectively (1,2). The latter test was reported to be enriched in nuclides belonging to volatile decay chains (neptunium-239, ruthenium-103, iodine-131 and barium-140) (3). The May test took place in the spring when most dairy cows normally are on pasture in the continental United States,<sup>2</sup> while the December test occurred when most dairy cows are not on pasture.

This report compares the environmental radioactivity levels observed in various media following the two reported nuclear weapons

tests (1,2) and discusses the influence of dairy practices and precipitation on these results.

### Data presentation and discussion

Fresh fission products attributable to foreign nuclear weapons tests were first detected on air filters which were removed on the morning of the fifth day after each test from stations located in the northwestern United States. The fresh fission products in surface air moved southward and eastward and covered most of the United States by the tenth day after the tests. Although the yield and the time of arrival of fission debris over the United States were approximately the same for both tests, large differences existed in the radioactivity found in various environmental media and in the relationship between these media.

The highest gross beta radioactivity in surface air particulates at a Radiation Surveillance Network (RSN) station was observed at

<sup>1</sup> Mr. Snavely is staff officer, Radiological Health Standards Section, and Mr. Brill is staff officer, Radiation Exposure Intelligence Section, both with the Standards and Intelligence Branch, National Center for Radiological Health.

<sup>2</sup> Hawaii and Alaska are excluded in this report.

Phoenix, Ariz. ( $15 \text{ pCi/m}^3$ ), 11 days after the May test, and at Las Vegas, Nev. ( $119 \text{ pCi/m}^3$ ), 6 days after the December test (5,6). The highest monthly gross beta radioactivity deposition from rainfall measured at RSN stations was at Jefferson City, Mo. ( $576 \text{ nCi/m}^2$ ) and at Portland, Ore. ( $2,545 \text{ nCi/m}^2$ ) for the former and latter tests, respectively. The highest monthly deposition after the May test occurred mainly in the mid-section of the United States south of the Great Lakes and in the northeastern section of Florida (figure 1). The highest monthly deposition after the December test occurred along the northern section of the west coast, northern Utah, the area west of Lake Michigan, and in northern Vermont (figure 2). The monthly gross beta radioactivity depositions for May 1966 and January 1967 were used for comparison purposes because increases were not observed until 4 or 5 days after the tests and continued for approximately 2 weeks. Consequently, increased gross beta radioactivity depositions after the two

tests occurred almost exclusively during these intervals.

#### *Air versus precipitation radioactivity concentrations*

Moeken and Alderhout derived a relationship between air concentrations and deposition by precipitation (7). A similar analysis was made utilizing the principles of Moeken and Alderhout to see if a correlation existed between the product of the gross beta radioactivity measured in air and inches of rainfall with gross beta radioactivity deposition on land for either test.

The data were grouped by the nine Department of Health, Education, and Welfare administrative regions (figure 3). Data for New Orleans, La. were grouped with Region IV. Precipitation data were obtained from the daily weather maps prepared by the U.S. Weather Bureau for the periods May 8 to June 4, 1966 and January 1 to January 28, 1967 (8). Environmental radioactivity data were obtained

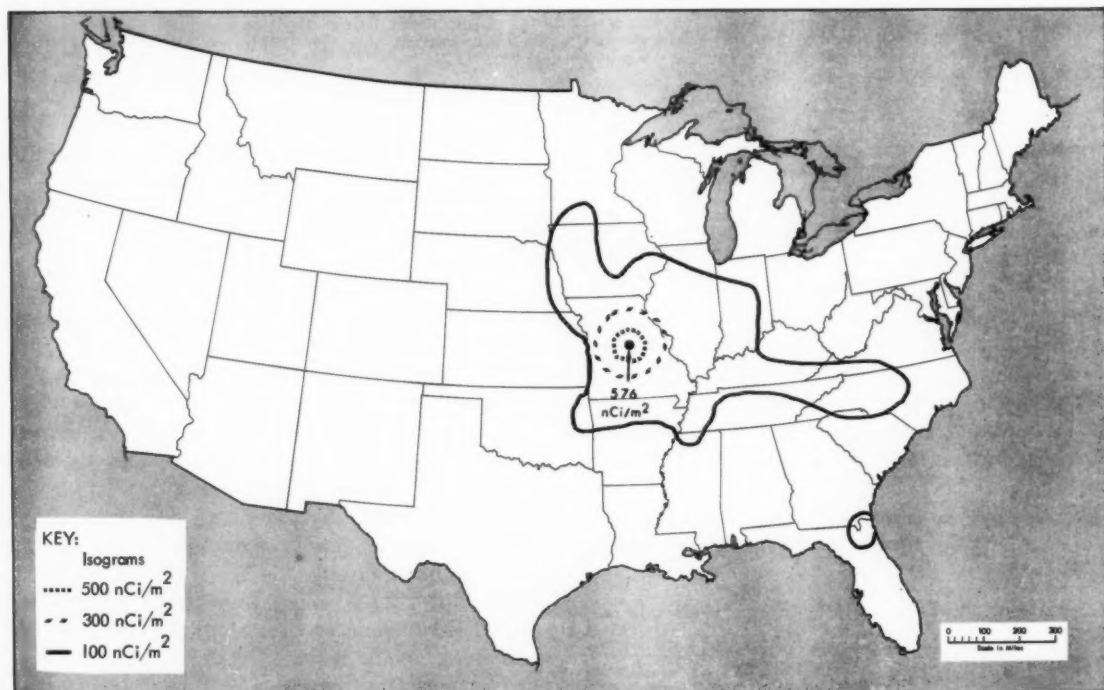


Figure 1. Isograms of gross beta radioactivity deposition during May 1966, estimated from gross beta radioactivity deposition measured at RSN stations

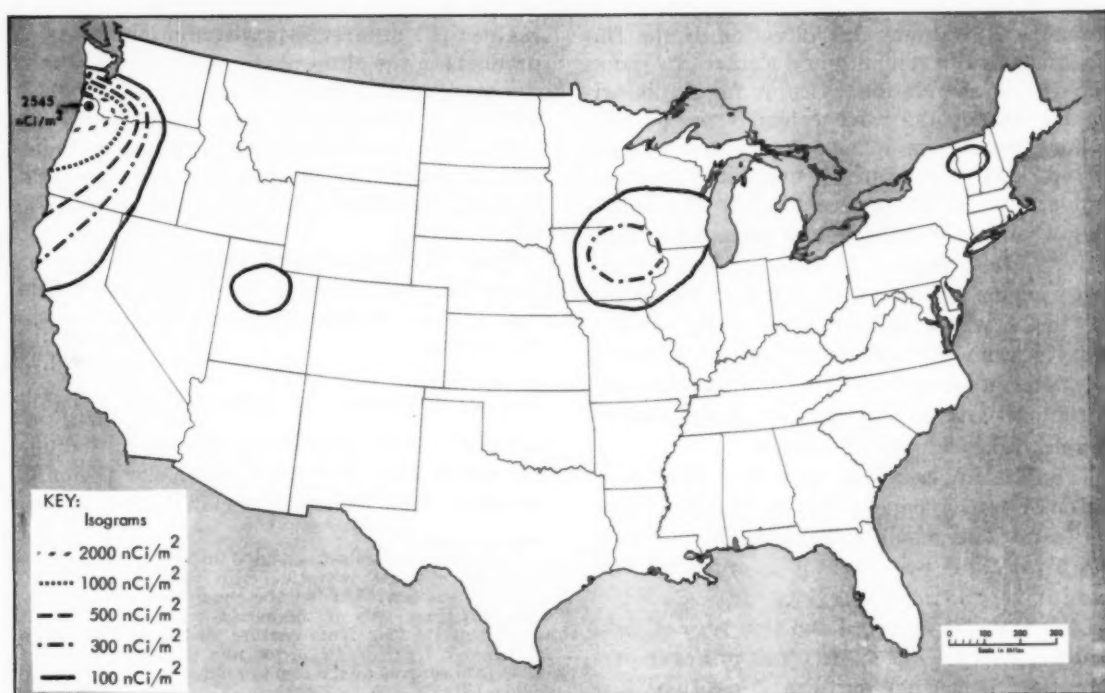


Figure 2. Isograms of gross beta radioactivity deposition during January 1967, estimated from gross beta radioactivity deposition measured at RSN stations



Figure 3. Department of Health, Education, and Welfare administrative regions

from the RSN under the direction of the Environmental Surveillance and Control Program (ESCP) of the National Center for Radiological Health for the same calendar period (9).

For the purpose of data analysis, it was assumed that the average precipitation in a region for any given week fell on the entire region. Also, the deposition of gross beta radioactivity was assumed to have fallen over the entire region and was averaged over the region for the 4 weeks following the tests. Radioactivity from particulates in air for a region was determined by averaging the total amount of radioactivity on air filters by the number of samples taken during the week.

The data for each test were then plotted by region on log-log paper for each week following the tests. The results are shown in figures 4 and 5 for these tests, and it is apparent that there is very little correlation.

Discrepancies arising from this type of data analysis may be due to (a) non-uniform precipitation, hence non-uniform deposition in a

region; (b) difference in distribution of fission products in the atmosphere with each pass over the country; (c) decay of short-lived products with time, resulting in less radioactivity depositing or fractionation of the measured radioactivity; and (d) samples assayed near the limit of detectability may have introduced unknown errors.

This precludes any relationship between gross beta radioactivity in air and gross beta radioactivity in deposition, except in very general terms.

#### Pasture half-times<sup>3</sup> of iodine-131

Table 1 lists pasture half-times of iodine-131 which best fit the milk data for the milk sampling stations and the cumulative iodine-

<sup>3</sup> "Pasture half-times" as used in this paper, represents the effective reduction with time of iodine-131 intake of the cow. This will be equal to the actual pasture half-times only if the cow is getting a constant amount of its food from pasture each day; inhalation of iodine-131 can be neglected and it is assumed that other food sources of the cow are not contaminated with iodine-131.

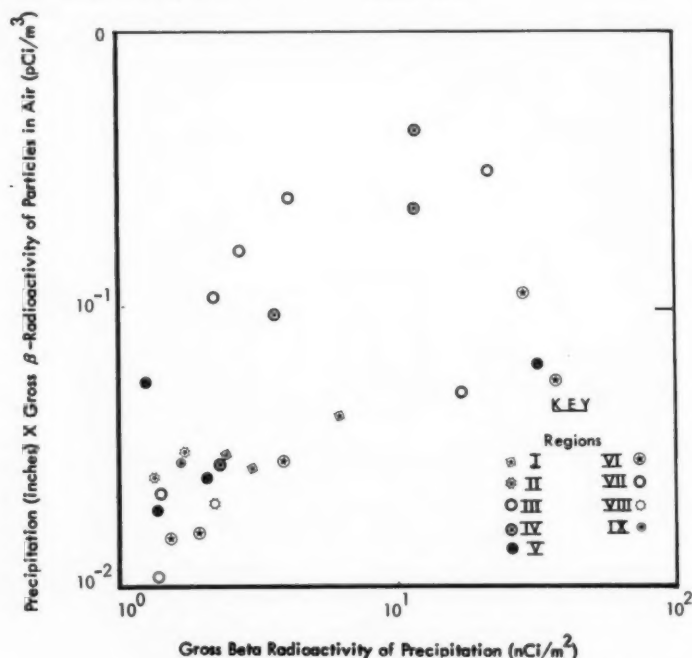


Figure 4. Correlation between average gross beta air radioactivity times average inches of precipitation versus average gross beta radioactivity deposition through rain for the period, May 8-June 4, 1966

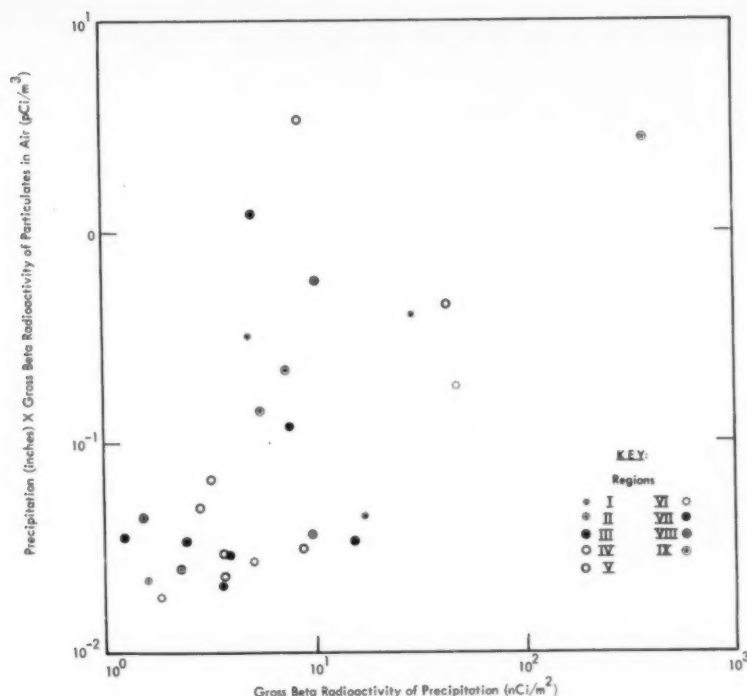


Figure 5. Correlation between average gross beta air radioactivity times average inches of precipitation versus average gross beta radioactivity deposition through rain for the period, January 1-28, 1967

<sup>131</sup>I intake, assuming milk consumption of 1 liter per day. The results of the May 9, 1966 test and the method of obtaining the pasture half-times and cumulative iodine-<sup>131</sup> intake have been described previously (10). The criteria for determining these values are:

1. at least one sample from the sampling station site has a milk concentration of iodine-<sup>131</sup> of 50 pCi/liter or greater,
2. samples were collected at least once a week at the sampling site,
3. the second milk sample from a sampling site was collected within 3 days of the collection date of the first milk sample with detectable iodine-<sup>131</sup> (>10 pCi/liter); or the iodine-<sup>131</sup> concentrations of the first milk sample was less than the iodine-<sup>131</sup> concentration of the second sample,
4. collection from a sampling site was continued until iodine-<sup>131</sup> concentrations in milk were below detectable levels.

The milk sampling frequency was less than that required by criterion (3) for the December test for most stations. Only ranges of cumulative iodine-<sup>131</sup> intakes could be given. In addition, the two California State sampling locations did not meet criterion (4), although the iodine-<sup>131</sup> concentrations were near detectable limits for the last samples reported.

Table 1 shows that the pasture half-times were generally longer for the May test than for the December test. The sampling frequency mode was 9 days for the May test and 4 days for the December test. The lowest pasture half-times for the May test was 4 days compared to 1 day for the December test. The short pasture half-time of 1 day indicates that the iodine-<sup>131</sup> intake was for a brief period of time (1 to 2 days). Dry lot feedings (if the feed is spread out each day) and a deposition time of only 1 or 2 days would account for a short iodine-<sup>131</sup> intake period. This explanation is plausible

Table 1. Pasture half-times and estimated human iodine-131 cumulative intakes from drinking milk after foreign nuclear tests of May 9, 1966, and December 27, 1966

Sampling location	Sample origin <sup>a</sup>	Pasture half-times (days)		Cumulative iodine-131 intakes <sup>b</sup> (pCi)	
		May test	December test	May test	December test
Ala: Montgomery.....	P	9	4	870	920-1,200
Ark: Little Rock.....	P	4	—	5,800	—
Green County.....	S	4	—	6,000	—
Lonoke County.....	S	4	—	5,000	—
Miller County.....	S	4	—	1,500	—
Ouachita County.....	S	4	—	1,900	—
Sebastian County.....	S	4	—	9,300	—
Washington County.....	S	4	—	6,500	—
Calif: Del Norte County.....	S	—	3	—	2,600
Humboldt County.....	S	—	3	—	2,200
Ga: Atlanta.....	P	9	4	980	920-1,100
Ind: Indianapolis.....	P	5	—	2,200	—
Fort Wagner.....	S	9	—	1,400	—
Indianapolis.....	S	9	—	2,100	—
Rochester.....	S	8	—	3,100	—
Iowa: Des Moines.....	P	9	—	1,100	—
Kans: Wichita.....	P	9	—	1,900	—
Minn: Minneapolis.....	P	4	—	810	—
Miss: Jackson.....	P	58	—	920	—
Mo: Kansas City.....	P	9	—	2,200	—
St. Louis.....	P	9	—	3,800	—
Nebr: Omaha.....	P	9	—	1,600	—
N. C: Charlotte.....	P	58	—	1,300	—
Ohio: Cincinnati.....	P	8	—	760	—
Okla: Oklahoma City.....	P	9	—	2,200	—
Enid.....	S	9	—	1,200	—
Lawton.....	S	9	—	1,300	—
Ore: Portland.....	P	—	8	—	820-1,000
Redmond.....	S	—	1	—	430
S. C: Charleston.....	P	9	3	1,200	1,300-3,600
Tenn: Memphis.....	P	9	—	1,400	—
Tex: Austin.....	P	9	5	620	1,200-1,400
Dallas.....	P	9	5	1,200	750-1,100
Lubbock County.....	S	9	—	1,100	—
Austin.....	S	—	4	—	1,000-1,500
Houston.....	S	—	4	—	2,900-4,500
Utah: Salt Lake City.....	S	—	1	—	170
South Utah County.....	S	—	1	—	370

<sup>a</sup> P—PMN sample.

S—State sample.

<sup>b</sup> One liter/day consumption rate assumed.

<sup>c</sup> Dash indicates no sample.

<sup>d</sup> Start of iodine-131 cow intake was assumed to have occurred January 1.

<sup>e</sup> Start of iodine-131 cow intake was assumed to have occurred after December 31.

since the majority of the gross beta radioactivity deposition measured at the Portland, Ore. RSN station occurred during January 1 and 2, and cattle in the Portland coastal region and in Humboldt and Del Norte counties of California were receiving only 10 percent of feed value from pasture. If the other 90 percent of the feed value was received through feed put out each day, the cows would have ingested iodine-131 deposited on stored feed placed outside on January 1 and 2 (the days when most of the gross beta radioactivity deposition occurred at Portland).

#### *Estimates of iodine-131 intake versus deposition*

All sampling locations of the PHS Pasteurized Milk Network (PMN) and those reported by the States are shown in figures 6 and 7. Sampling locations where iodine-131 was detected are indicated on these figures. Concen-

trations of 20 pCi/liter or greater was taken as the minimum detection limit for this study, except for Idaho (50 pCi/liter minimum detection limit) and Vermont (80 pCi/liter minimum detection limit). Total intake isograms of the cumulative iodine-131 intakes were drawn from the values and sampling locations given in table 1. All samples collected outside the 1,000 pCi isogram line had iodine-131 concentrations of 60 pCi/liter or less. Exceptions were: figure 6—several samples collected in Utah where the highest sample was reported as 270 pCi/liter; figure 7—two samples from Alabama, one sample from North Dakota, one sample from Tennessee, and three from Utah which were all below 125 pCi/liter.

Milk samples collected at PMN stations represent a composite of the milk sold in the area. As the PMN samples generally are representative of the milk produced over large areas rather than small areas, they do not serve to

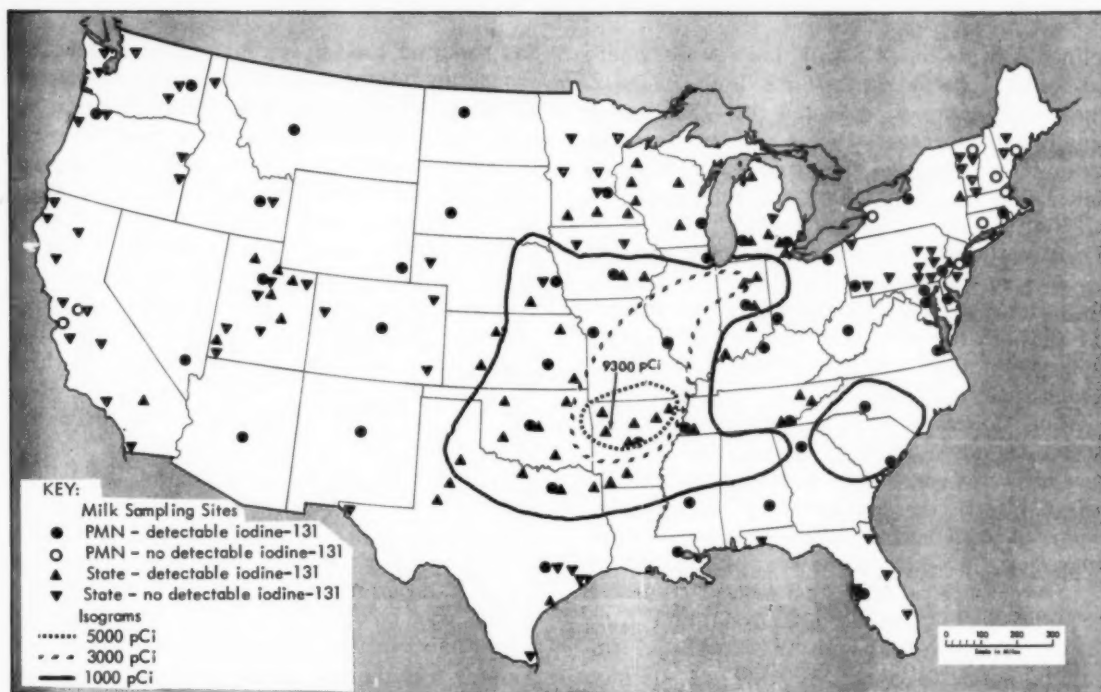


Figure 6. Isograms of estimated iodine-131 intake from drinking 1 liter of milk per day following the nuclear weapons test of May 9, 1966

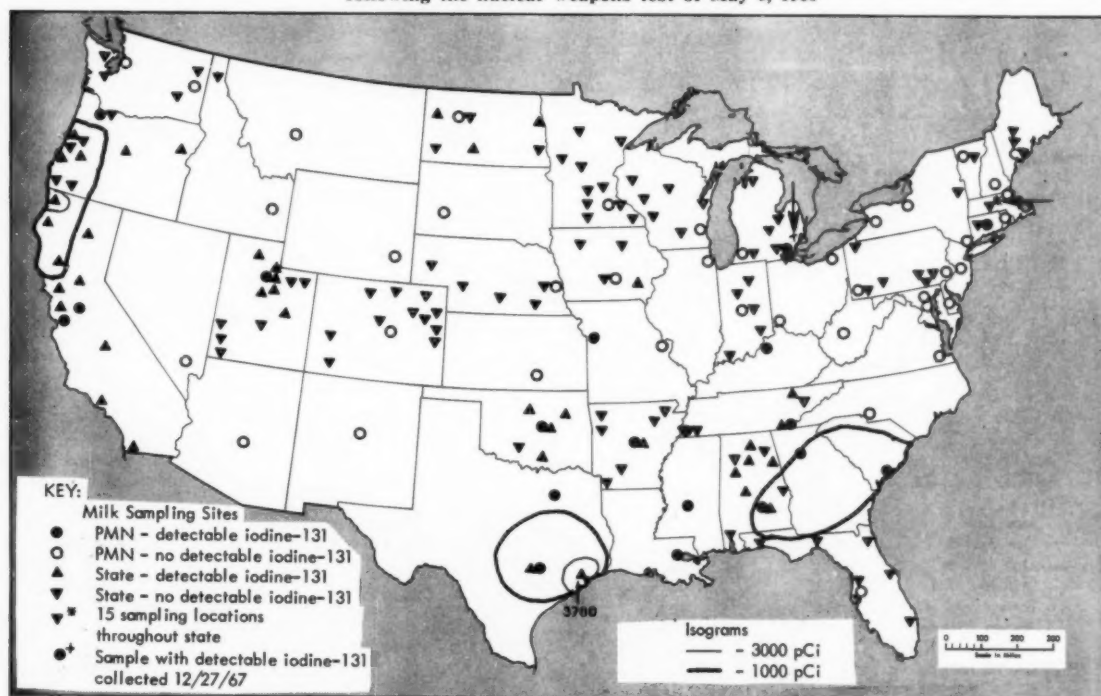


Figure 7. Isograms of estimated iodine-131 intake from drinking 1 liter of milk per day following the nuclear weapons test of December 27, 1966

delineate in as much detail those areas where iodine-131 concentrations are high in milk. The milk samples collected by the States usually are representative of milk produced in areas of smaller size than are PMN samples. Hence, State milk samples define in more detail high or low regions of iodine-131 in milk. When available, the State data were used to draw isograms, rather than the PHS results. The isograms of estimated cumulative iodine-131 intake after the May test roughly correspond to the area which had the greatest gross beta radioactivity deposition (figures 1 and 6).

When figures 2 and 7 are compared, the estimated iodine-131 intake isograms for the December test correspond to the deposition isograms only in the northwestern coastal area. A partial explanation for this can be obtained from figure 8 which gives some indication of pasture conditions after this test. Except for the West Coast, southern Arizona and New Mexico, Texas, Oklahoma, the Southeast extending north to parts of Missouri, Illinois, Indiana, Ohio, West Virginia, and Virginia, pastures were covered with snow (11). Olsen

has reported the approximate dates cattle are on pasture (4). Only cattle in the Deep South and in California would be expected to be on pasture (figure 8) during an average winter. With the exception of the Oregon coast, these were the locations where the highest intakes of iodine-131 were determined.

Comparisons were made of the areas within the 1,000 pCi iodine-131 intake isograms following the two tests. The northwestern Oregon area, following the December test, had higher gross beta radioactivity deposition than the Missouri-Arkansas area following the May test, but had lower iodine-131 intake estimates (suggesting that cows were receiving less of their food from pasture). However, the southeastern Texas and South Carolina-Georgia-Alabama areas had iodine-131 intake estimates as high or higher than in the Oregon area following the December test even though the deposition was below 100 nCi/m<sup>2</sup>. Areas having depositions of 100 nCi/m<sup>2</sup> or greater following the May test showed iodine-131 intakes similar to or higher than iodine-131 intake in Oregon following the December test. Areas with

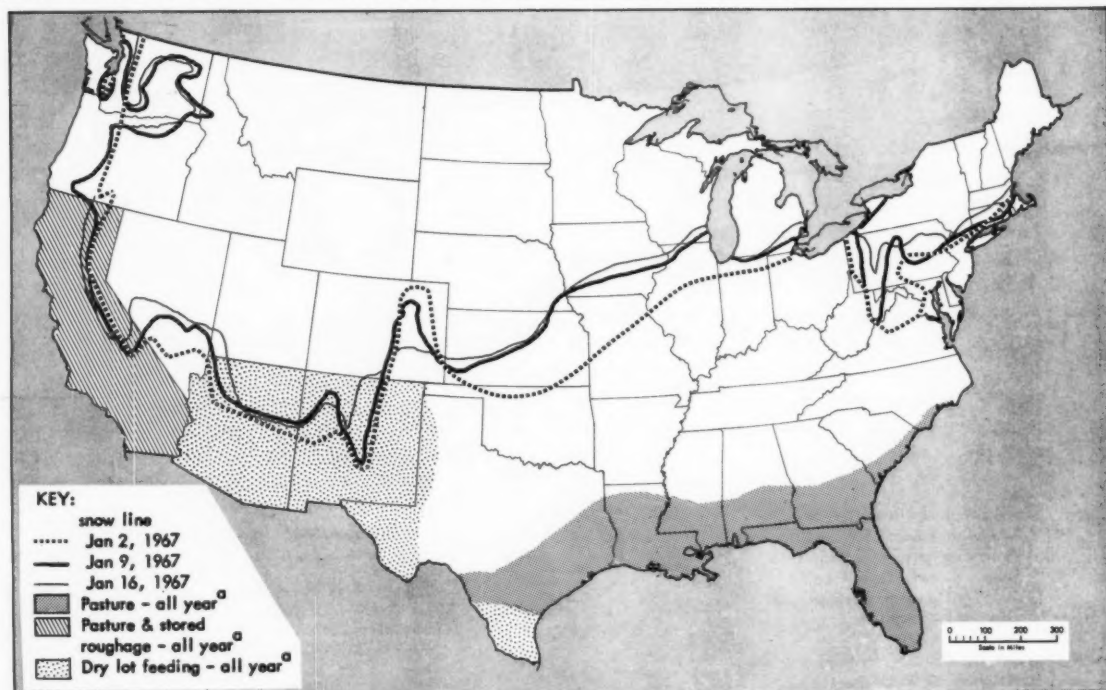


Figure 8. Pasture conditions

iodine-131 intakes following the December test similar to that in Oregon had gross beta radioactivity deposition less than 100 nCi/m<sup>2</sup>. A possible reason for these results would be a slower pasture growth requiring the cows to graze a larger area, and thus increase their daily iodine-131 intake.

#### *Summary and conclusions*

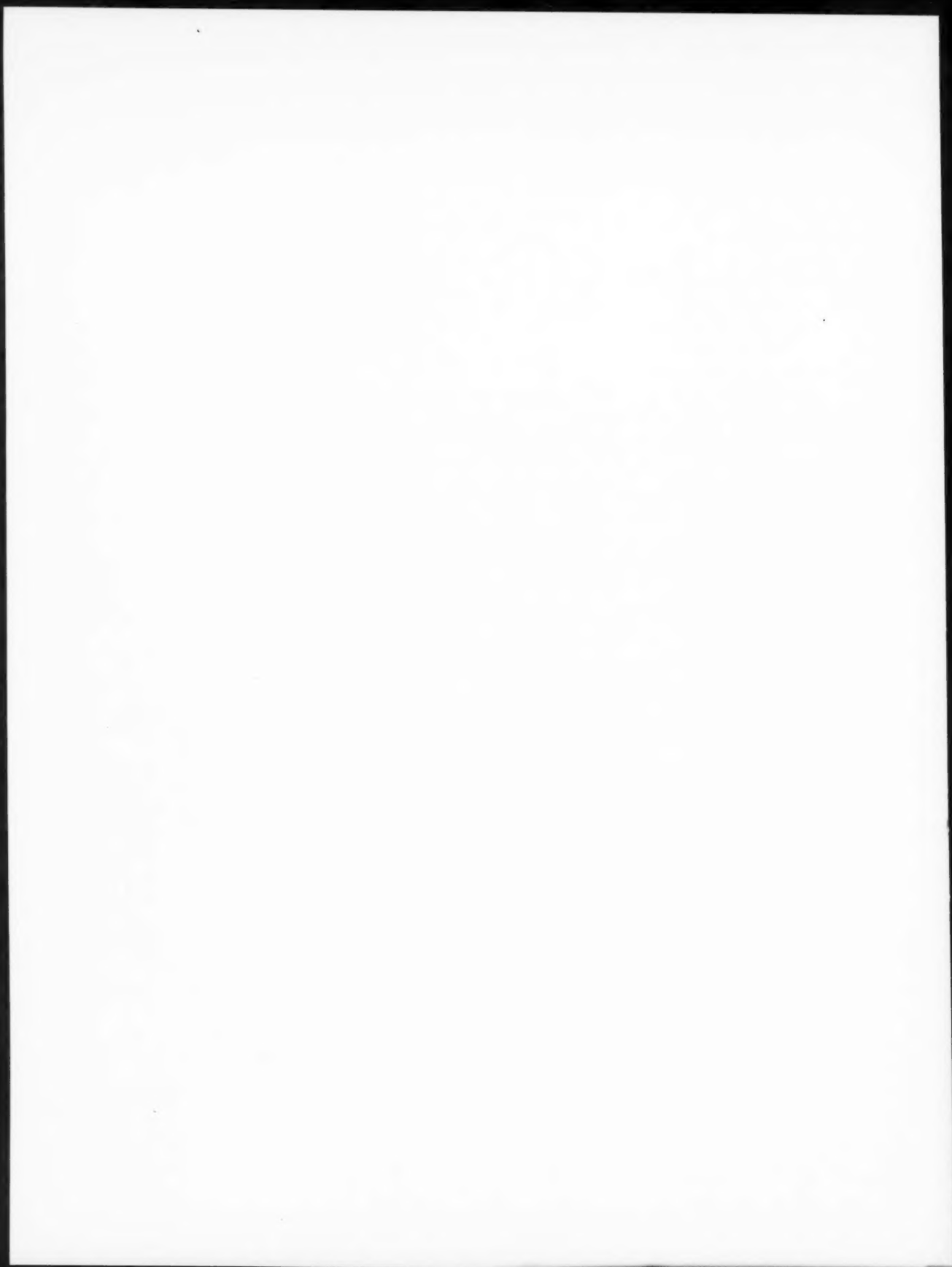
The highest gross beta radioactivity of surface air particulates, the highest gross beta deposition by precipitation, and the highest contribution of nuclides belonging to volatile decay chains (including iodine-131) were found after the December 27, 1966, foreign nuclear weapons test. The highest cumulative iodine-131 intakes from drinking 1 liter of milk per day were estimated to be for the time period after the May 9, 1966, foreign nuclear weapons test. This is considered to result, in part, from the inferred different dairying practices after the two tests. After the May test, presumably all the cows with the exception of those in dry lot feeding areas were out on pasture. After the December test only those in the Deep South and in California were presumed to be on pasture. Another contributing factor was the more rapid elimination of iodine-131 from the cows' feed, which is indicated by the shorter pasture half-time found during the December test. This again points to differences in dairying practices or weather conditions or a combination of both and points out the importance of considering dairying practices when attempting to predict the amount of iodine-131 expected in milk as a function of deposition.

#### *Acknowledgment*

The authors wish to express their appreciation for the assistance received from the State personnel represented by the programs mentioned herein, without whose assistance this report would not have been possible.

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# Technical Notes

## Offsite Environmental Surveillance Findings Associated With Underground Nuclear Testing; Project Dribble

Hubert D. Harvey, Jr. and Melvin W. Carter<sup>1</sup>

Two detonations, termed the Salmon event and the Sterling event, Project Dribble, took place on October 22, 1964, and December 3, 1966, respectively. These detonations were a part of the Department of Defense (DOD)—Atomic Energy Commission's (AEC) seismic research program called Vela Uniform, which is designed to improve U.S. capabilities to detect, identify, and locate underground nuclear detonations.

Both events took place approximately 2,720 feet underground in a salt formation known as the Tatum Salt Dome, 19 air miles southwest of Hattiesburg, Miss. The Salmon shot was a 5-kiloton nuclear detonation in a tamped emplacement (one in which the shot chamber is as small as possible). The Sterling shot was a decoupled detonation (fired in the center of a cavity to study the reduction of ground shock and long-range seismic signal transmission) of a nuclear device of approximately 350 tons, conducted in the 110-foot diameter, roughly spherical cavity formed by the Salmon shot. The location of the test site is shown in figure 1.

The offsite program was conducted by the National Center for Radiological Health (NCRH) staff consisting of personnel from the regional laboratories (Southeastern Radiological Health Laboratory, Southwestern Radiological Health Laboratory, and Northeastern Radiological Health Laboratory), and PHS reserve officers recruited for temporary duty.

In addition, a medical officer and a veterinary officer were on full-time duty in Hattiesburg. The operations included environmental sampling and analysis and ground and aerial monitoring. Also, because the program was conducted in a populous area, and involved the temporary evacuation of offsite residents of the immediate vicinity, a personalized public relations program constituted an important feature of the program.

A description of the organization of the operation and of the procedures in support of the Salmon event has been published (1). The same general procedures were followed for the Sterling event.

An environmental sampling program was initiated during April and May 1963 for the collection of background radiation data. Milk, water, vegetation, and air were sampled routinely before and after the shots. The types of sampling done are shown in figure 2.

### Procedure

In order to meet any possible emergency associated with contamination of milk in the off-site area, surveys were conducted in coordination with the State Health Departments of Mississippi and Louisiana. Data were assembled concerning approximately 1,600 dairy farms, 30 milk processing plants, and details concerning bulk-truck collections. The information gathered was utilized to establish a composite milk sampling program within a 50-mile radius of the test site. Sampling stations for 12 milk routes, representing 219 dairy farms, were established.

<sup>1</sup> Mr. Harvey is chief, Engineering Services, SERHL; and Dr. Carter is director, Southeastern Radiological Health Laboratory, Montgomery, Ala.



Figure 1. Test site location map

The environmental sampling program, initiated in May 1963, in preparation for the Salmon event, included air, milk, water, vegetation, and other selected media. The samples were representative of an area bounded by a 50-mile radius of the test site. This coverage would be supplemented with mobile sampling capacity at shot time.

As nearly as possible, the collection of routine samples was coordinated with local residents; that is, offsite residents were recruited to operate permanent air sampling stations, and in certain instances, to assist in the collection of milk and water samples.

The environmental sampling coverage which was established prior to the Salmon shot is shown in figure 2 and tabulated below. The film badge coverage and locations of background recorders are also shown in figure 2.

The sampling program for the Sterling event was essentially the same as for Salmon with the exception that 10 less water stations and 13 less one-cow-family type milk stations were in operation for Sterling than for Salmon. Also, fewer personal film badges were distributed for Sterling than for Salmon. These small differences in environmental coverage were associated with (1) the differences in the predic-

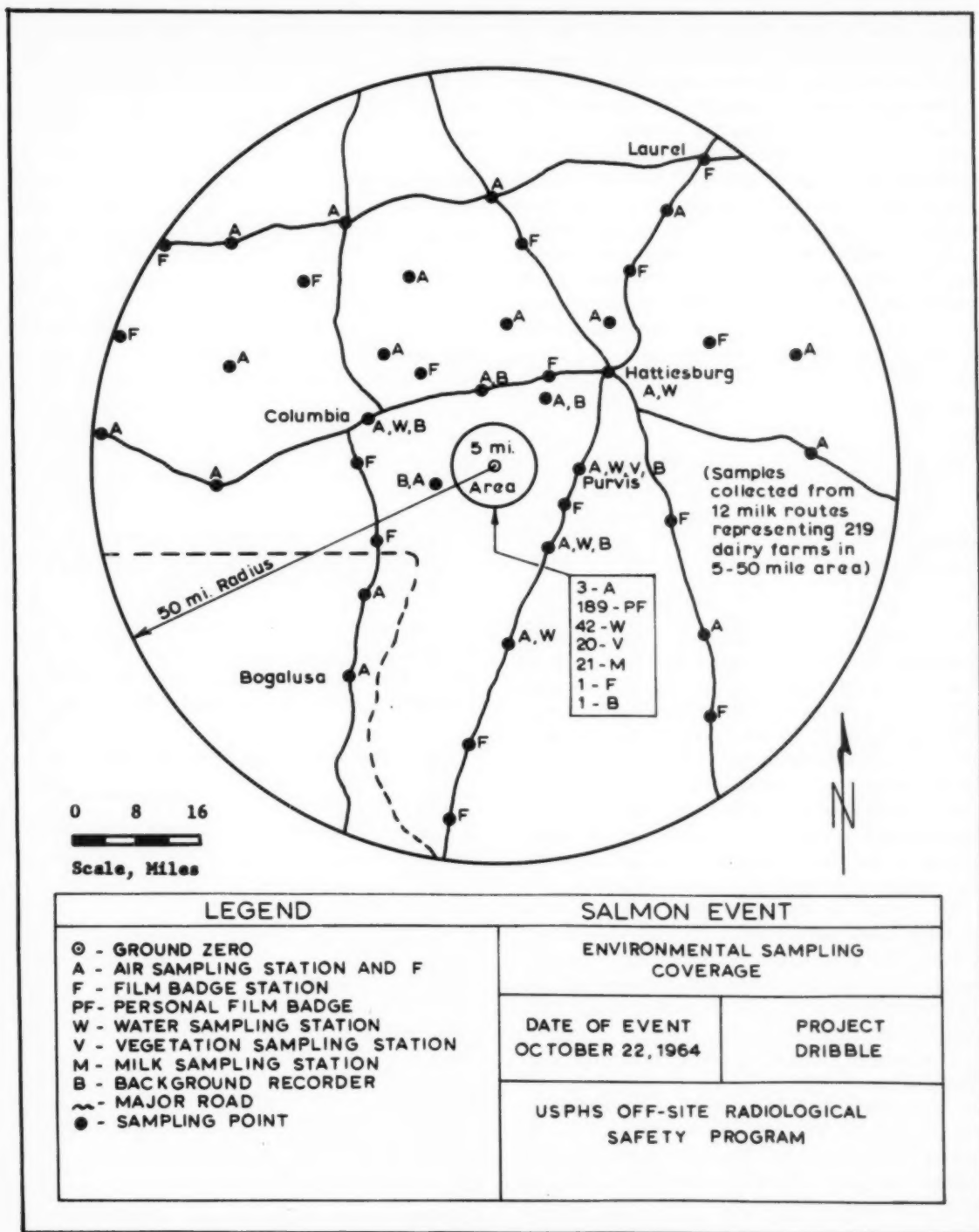


Figure 2. Environmental sampling coverage

tions for a maximum credible accident for the two events, and (2) availability of samples. It was predicted that the area of interest, as associated with possible radiation levels, would be greater for Salmon than for Sterling if an accident occurred, although generally similar coverage was required for both events as a precautionary measure. Also, the availability of samples, especially one-cow-type samples within a 5-mile radius was not the same for Sterling as for Salmon, *i.e.*, fewer cows were being milked at this particular time.

Type of sample	Number of stations
Air -----	27
Milk -----	21 (1-2 cows) 12 milk routes (composite samples)
Water -----	47
Vegetation -----	21

A counting laboratory was established in Hattiesburg prior to each event for possible use in an emergency. The routine samples which were collected for background purposes were analyzed at the Southeastern Radiological Health Laboratory, Montgomery, Ala., and reports issued on a monthly basis. Special samples collected at shot time were counted at the Hattiesburg laboratory, the facilities of which included analytical capability for alpha, beta, and gamma radioactivity determinations.

In addition to the laboratory in Hattiesburg, a mobile laboratory was utilized for the Salmon event. This laboratory had facilities to analyze samples for alpha, beta, and specific gamma radioactivity and it could be moved easily from one location to another.

The results of analyses of special milk samples collected during Salmon from October 21 to November 6, 1964, from noncommercial sources within a 5-mile radius of the test site are shown in table 1. Small concentrations of iodine-131 were detected in vegetation samples and gross beta concentrations in air particulate samples increased slightly during this period. This rise in activity is attributed to the general-

Table 1. Salmon event, milk data,<sup>a</sup> (October 21-November 6, 1964)

Collection date (1964)	Radioactivity		
	Iodine-131 <sup>b</sup> (pCi/liter)	Cesium-137 (pCi/liter)	Potassium (g/liter)
10-21-64.....	<10 *	70	1.42
10-23-64.....	<10 *	165	1.80
	<10 *	120	1.28
	<10 *	65	1.03
	<10 *	100	1.69
	<10 *	75	1.63
10-26-64.....	<10	220	1.33
	<10	85	1.44
	<10	40	1.79
	<10	55	1.75
	15	160	1.39
	<10	80	1.45
	<10	180	1.87
	<10	100	1.58
	17	60	.86
	<10	70	1.40
10-27-64.....	35	55	1.32
	20	195	1.66
	<10	50	1.75
	<10	105	1.36
	19	125	1.62
	<10	80	1.58
11-5-64.....	49	65	1.64
	49	280	1.67
	54	75	1.01
11-6-64.....	47	200	1.20
	78	255	1.72
	26	70	1.67

<sup>a</sup> Refer to table 4 for explanation of analytical errors.

<sup>b</sup> Corrected for decay to date of collection.

<sup>c</sup> These samples were counted 11 to 13 days after collection. Therefore, the limit of detection for iodine-131 in reference to the date of collection will be approximately 30 pCi/liter.

ized atmospheric fallout associated with the foreign atmospheric nuclear test of October 16, 1964. A comparison of Radiation Surveillance Network (RSN) air sampling data with the

Table 2. Salmon event, composite milk sample data<sup>a</sup>

Sample collection date	Average radioactivity	
	Cesium-137 (pCi/liter)	Strontium-90 (pCi/liter)
1963		
May.....	160	18
June.....	170	21
July.....	165	17
August.....	155	17
September.....	125	16
October.....	125	17
November.....	125	18
December.....	130	18
1964		
January.....	150	18
February.....	160	19
March.....	200	26
April.....	195	27
May.....	165	26
June.....	120	21
July.....	110	21
August.....	100	18
September.....	90	18
October.....	80	17
November.....	70	15
December.....	70	17
1965		
January.....	65	17
February.....	75	17
March.....	90	17

<sup>a</sup> Refer to table 4 for explanation of analytical errors.

offsite surveillance data collected during the Salmon event is discussed later in this report.

The average background concentrations of strontium-90 and cesium-137 (at the time of count) in composite milk samples are shown by month in table 2. These samples were collected from April 1963 to March 1965 in relation to activities associated with Salmon, including post-shot activities. The number of samples submitted monthly ranged from 14 to 28, representing a maximum of 219 dairy farms within a 50-mile radius of the test site. In addition to cesium-137 and strontium-90, iodine-131, strontium-89, and barium-140 were detected in milk samples during this period of time.

The milk data for Sterling are shown in table 3. These data represent composite, commercial and noncommercial-type samples collected in November and December 1966 before and after the shot. The composite samples represent 220 dairy farms within a 50-mile radius of the test site; whereas the noncommercial samples were collected within a 5-mile radius of the site. The individual composite sample data represent, with a few exceptions, the same dairy farms for which average concentrations per sample are shown in table 2. The noncommercial samples were taken from certain of the same locations as were the samples for which data are given in table 1. The major difference in the milk sampling program for the Sterling

Table 3. Sterling event—results of milk analyses<sup>a</sup>

Collection date (1966)	Concentration				
	Potassium (g/liter)	Strontium-90 (pCi/liter)	Iodine-131 <sup>b</sup> (pCi/liter)	Cesium-137 (pCi/liter)	Barium-140 <sup>b</sup> (pCi/liter)
11/23.....	1.60	10	<10	25	<10
11/24.....	1.58	18	<10	15	<10
11/25.....	1.47	22	<10	15	<10
	1.57	34	10	25	<10
	1.57	19	<10	15	<10
	1.46	27	<10	30	<10
	1.44	32	10	15	10
	1.37	20	<10	15	10
	1.57	15	<10	20	<10
	1.49	16	<10	20	10
	1.57	14	<10	25	<10
	1.37	11	<10	25	<10
11/26.....	1.55	32	10	15	10
	1.47	27	<10	25	<10
	1.44	27	<10	40	<10
	1.58	21	<10	35	<10
11/27.....	1.47	21	<10	25	<10
11/28.....	1.64	8	<10	30	<10
11/30.....	1.52	112	<10	35	<10
	1.20	41	20	25	<10
	1.55	13	<10	25	<10
	1.88	108	20	85	20
	1.64	12	<10	45	<10
	1.40	14	20	30	20
	1.15	62	<10	65	10
12/12.....	1.54	22	<10	15	<10
	1.38	26	<10	15	<10
12/13.....	1.47	22	<10	20	<10
	1.47	24	<10	30	<10
	1.41	29	<10	25	<10
	1.48	30	<10	20	<10
	1.43	23	<10	15	<10
	1.46	20	<10	25	<10
	1.58	22	<10	10	<10
	1.50	20	<10	15	<10
	1.48	25	<10	25	<10
12/14.....	1.51	18	<10	15	<10
	1.45	17	<10	20	<10
	1.56	23	<10	25	<10
	1.47	29	<10	15	<10
	1.65	31	<10	25	<10
	1.57	25	<10	45	<10
	1.44	26	<10	20	<10
12/15.....	1.44	125	<10	40	<10
	1.21	41	<10	30	<10
	1.56	49	<10	65	<10
	1.76	77	<10	125	<10
	1.55	45	<10	45	<10
	1.34	103	<10	30	<10
	1.13	36	<10	20	<10

<sup>a</sup> Refer to table 4 for explanation of analytical errors. The concentration of strontium-89 in all samples was less than 5 pCi/liter.

<sup>b</sup> Data have been corrected for decay to the date of sample collection.

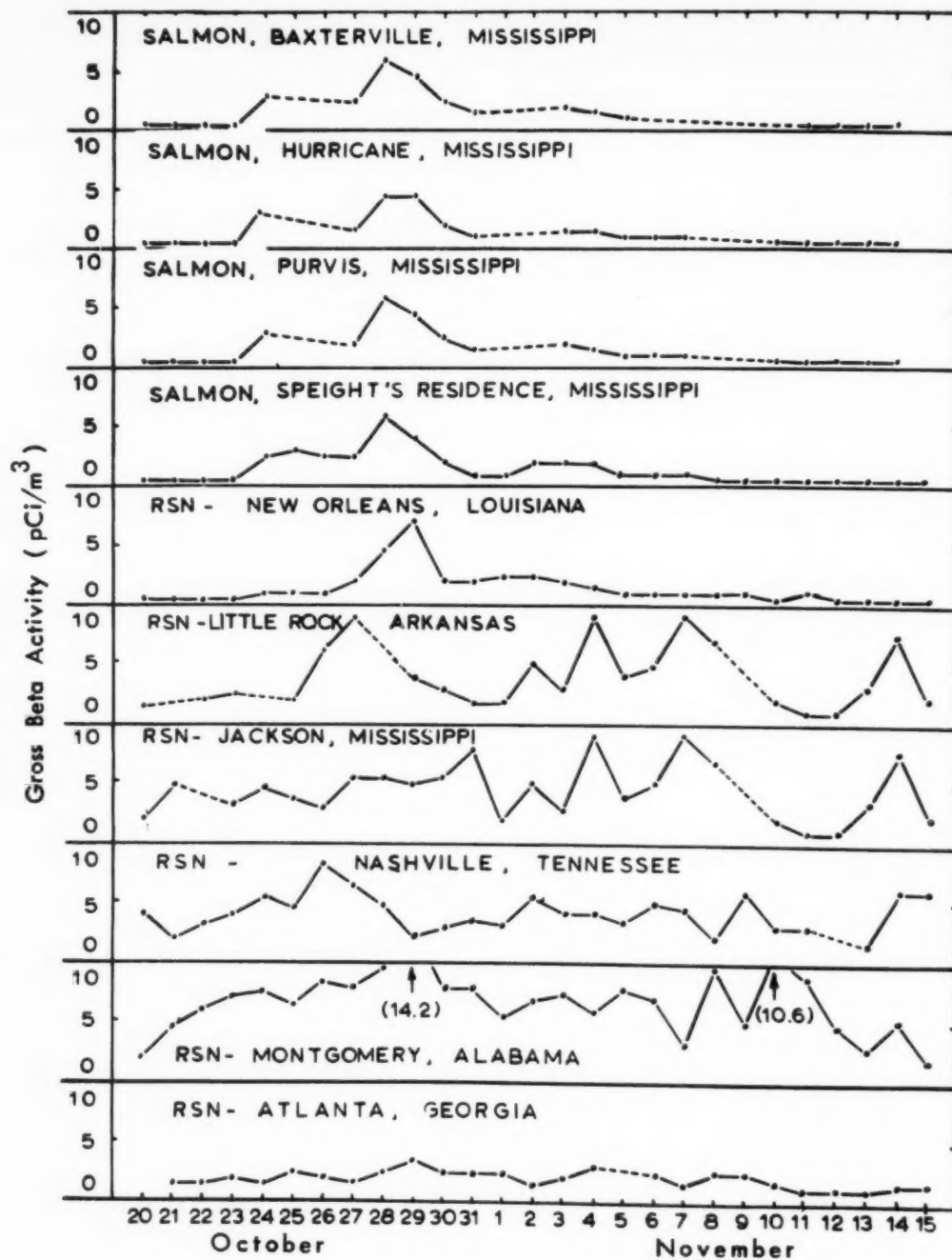


Figure 3. Comparison of Salmon event and RSN air sampling data

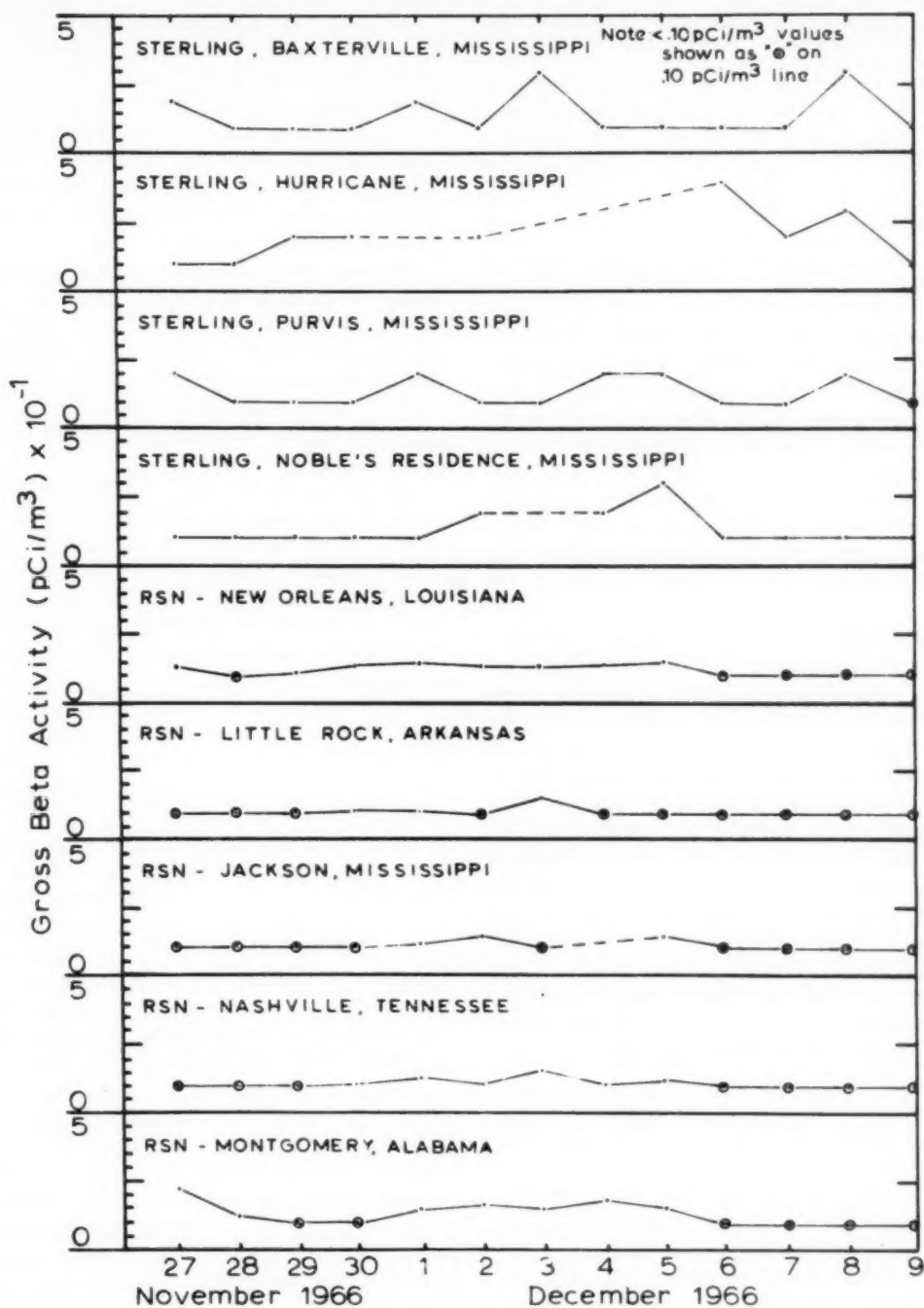


Figure 4. Comparison of Sterling event and RSN air sampling data

Table 4. Analytical errors associated with determinations of radionuclide concentrations in milk<sup>a</sup>

Radionuclide	Concentration (pCi/liter)	Error <sup>b</sup> (pCi/liter)	Concentration (pCi/liter)	Error <sup>b</sup> (percent of concentration)
Iodine-131-----	<100	10	≈ 100	10
Barium-140-----	<100	10	≈ 100	10
Cesium-137-----	<100	10	≈ 100	10
Strontium-89-----	< 50	5	≈ 50	10
Strontium-90-----	< 20	2	≈ 20	10

<sup>a</sup> This table is approximate and should not be used for precise determinations of errors.

<sup>b</sup> Two standard deviations.

event in comparison to the Salmon event was that between 1964 and 1966 a number of dairy-men went out of business; therefore, it was impossible to sample the same dairy farms for the two events. This situation was true for the noncommercial sampling program, *i.e.*, less people were milking cows within a 5-mile radius of the site in 1966 than in 1964; therefore, the number of offsite milk sampling stations for Sterling was not the same as for Salmon.

As previously indicated, a rise in gross beta radioactivity levels was detected in late October and early November of 1964, during the same time period as the Salmon shot; however, air radioactivity data from PHS, RSN stations in this general area also indicated this rise in activity, with the exception of Atlanta, Ga. This indicates that the radioactivity detected in the area of the Salmon shot was most probably a part of generalized atmospheric fallout attributed to the foreign atmospheric nuclear test conducted in the atmosphere on October 16, 1964. Figure 3 presents a comparison of air data for a selected number of Salmon stations with RSN data (1), and figure 4 shows a similar comparison of Sterling air data.

No radioactivity above background was detected in the local offsite environment during Salmon or Sterling that could be attributed to either of the shots. A continuous program of water sampling has been conducted around the test site area since the spring of 1963. The sampling program includes private, stream, and public supplies. No radioactivity above background has been detected.

During both events, ground monitoring teams were employed in the field. An average of 27 ground monitoring teams participated during both events. Each team was equipped with beta-gamma-type field survey instruments, and mobile air sampling capability. They were directed in the field through a central radio control system.

An aerial monitoring team as well as an aerial cloud sampling team participated in both events. The teams were employed in the field until project officials determined that it was safe to terminate radiation monitoring activities. All aerial monitoring activities for the two events indicated no radioactivity above background.

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## Suggested Biological Monitoring for Radon Daughter Exposure

Victor E. Archer<sup>1</sup>

Methods for accurately determining the radiation exposure of underground uranium miners have become of increasing importance since official action has been taken to keep their exposures below specified limits (1). Discussed in this note are the present monitoring techniques for radon daughter exposure and suggested biological indicators that may prove useful for determining radon daughter exposure.

### *Air sampling*

Periodic air sampling for radon daughters is the only method currently used to estimate exposure. This method has several inherent defects as a means of determining the exposure of individuals. First, marked fluctuations of radon daughter products occur in space and time within any mine. It is not practical to take air samples at the particular point where each man is breathing, so that air measurements rarely reflect with accuracy the radionuclide concentration in the air actually breathed. Also, fluctuations in air concentrations occur between the times that sampling is done. The longer the frequency between samplings, the greater is the opportunity for undetected fluctuations. Second, physical factors such as dust concentration, particle size distribution, humidity and temperature, which affect the fraction of airborne radionuclides that reaches the critical tissue, are uncontrollable variables. Third, physiological factors, such as rate and depth of breathing, degree of constriction of bronchi and bronchioles, thickness of mucus blanket overlying bronchial epithelium and pulmonary clearance rates are also uncontrollable factors in determining actual exposure to the critical tissue.

### *Biological indicators*

Because of the many uncontrollable factors involved in relating air concentrations to actual exposure of critical tissue, a biological monitoring system is highly desirable. Since the short half-life daughters of radon decay to lead-210 and polonium-210, which have relatively long half-lives, it seems reasonable to suppose that one or both of them could be measured in urine, feces, hair, or body tissues to serve as biological indicators of radiation exposure of men working underground in uranium mines.

A number of publications have reported urine and tissue analyses for these two radionuclides in uranium miners and in non-miners (2-18). One of these has established a quantitative relationship between cumulative exposure and bone concentrations of lead-210 (6). Although similar relationships have not been quantitatively established between exposure and other items of interest, the data referred to above (2-18) can be used to make estimates that should be useful in initiating biological monitoring programs, and will serve as guides until more precise data are developed. These estimates for urine are given in table 1.

It has been noted previously that the polonium-210 and lead-210 contents of urine reflect two different aspects of their metabolism (2). The first aspect, represented by the first four estimates in table 1, reflects that portion of polonium-210 and lead-210 that is rather promptly excreted following its intake. The second aspect, represented by the last four estimates in table 1, reflects a slow excretion rate from body deposits of these radionuclides. A comparison of the urine concentrations estimated to result from current exposure with those from cumulative exposure (largely bone deposits) indicates that those radionuclides in urine representing cumulative exposure will not

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**Table 1. Predicted concentrations of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in urine which correspond to selected radiation exposure values of interest for control purposes**

Selected exposures	Predicted radioactivity (pCi/liter)	
	$^{210}\text{Po}$	$^{210}\text{Pb}$
Estimated concentration in urine during exposure at 0.3 working level.....	0.2	0.3
Estimated concentration in urine during exposure at 1.0 working level.....	0.3	0.8
Estimated concentration in urine following cumulative exposure of 100 working level months after subject has stopped mining for 1 or 2 months.....	0.06	0.09
Estimated concentration in urine following cumulative exposure to 400 working level months after subject has stopped mining for 1 or 2 months.....	0.2	0.3

seriously interfere with measurement for current exposure until cumulative exposure approximates 400 working level months.<sup>2</sup> For a man whose exposure is considerably greater than 400 working level months, urinalysis would not likely be a practical means of evaluating subsequent exposure rates.

#### *Additional indicators*

Four other items are of special interest for monitoring purposes: bone, which is of value in estimating cumulative radiation exposure at death; blood, feces, and hair, which may be of value in estimating intensity of mine exposure in the recent past. Due to absence of data, no estimate can be made at this time for the radionuclide concentrations in blood or feces which might correspond to a current exposure at one working level. It is likely, however, that the concentrations in blood would not be much higher than that found in urine at the same point in time.

Since hair grows slowly, and reflects blood concentrations at the time of formation, hair radionuclide content may be expected to reflect blood concentrations averaged over a period of 6 to 15 months (depending on length of hair available for analysis) (21). Bone concentrations cannot be expected to reflect recent or current exposures to an appreciable extent.

<sup>2</sup> One working level is equivalent to 100 pCi of radon-222 at equilibrium with its daughters per liter of air. A working level month represents the cumulative radiation exposure for 1 month.

Hair and bone concentrations based on reported measurements which are estimated to correspond to designated radiation exposures are given in table 2 (2-18).

**Table 2. Predicted concentrations of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in hair and bone which correspond to selected radiation exposure values of interest for control purposes**

Selected exposures	Predicted radioactivity (pCi/g)	
	$^{210}\text{Po}$	$^{210}\text{Pb}$
Estimated concentration in hair following 6 to 15 months exposure at 0.3 working level.....	1.0	0.4
Estimated concentration in hair following 6 to 15 months exposure at 1.0 working level.....	3.0	1.0
Estimated concentration in bone within a few years after end of mining, which corresponds to 100 working level months.....	0.08	0.09
Estimated concentration in bone within a few years after end of mining, which corresponds to 400 working level months.....	0.2	0.3

The numbers given in tables 1 and 2 are likely to be correct within a factor of 2. Additional research is needed to refine them further. Crude as the numbers are, they may prove helpful in developing biological monitoring procedures to detect and/or prevent radiation over-exposure among uranium miners. The numbers in tables 1 and 2 corresponding to an exposure rate at 0.3 working level and to cumulative exposure of 100 working level months are not greatly different from normal values in non-miners. Biological monitoring at these levels will therefore present a problem unless very sensitive detection methods similar to ones recently described are used (4,16,19).

In addition to the radionuclide concentrations in urine and tissues mentioned above, it is quite possible that measurement of radionuclide concentrations in saliva or in a small amount of water used to rinse out the mouth at the end of a day's work would be useful for biological monitoring. As with blood and feces, insufficient work has been done with this material to warrant estimates of concentrations that might correspond to an 8-hour exposure at 0.3 or 1.0 working level. Measurement of saliva or mouth-rinses would probably require less sensitive equipment than the other measurements discussed above, as many of the short half-life

daughters of radon would be present. Separation of specific radionuclides might be unnecessary for monitoring purposes.

Even if the radionuclide concentration in hair can be shown to accurately reflect mine exposures, its use has four inherent drawbacks: (1) Expensive and time consuming sample preparation (hair must be digested before its content of alpha- or beta-emitters can be determined); (2) External contamination from radon and dust present in the air of mines (this would probably be difficult to wash off (20)); (3) Time element (concentrations in hair can not reflect over-exposures as they occur, but would reflect exposures which had occurred weeks before sampling (21)); (4) Differences in personal hygiene (the frequency of washing hair and face, and the different detergents employed, might result in different degrees of leaching, as well as different degrees of surface contamination of hair samples).

### Summary

Present methods of sample preparation and measurement appear to be too time consuming and delicate to be practical for routine monitoring purposes (2). To be practical, quicker methods which can be performed promptly by relatively untrained personnel, must be developed. Two methods appear to hold promise: determination of gamma rays from saliva or mouth-rinse by scintillation well-type counters, and determination of alpha or beta radiation from saliva, mouth-rinse, or urine after simple sample preparation by liquid scintillation counting systems. Development of some such simple system is urgently needed.

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## SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (1-3). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (3). Additional guidelines are provided by the

FRC Protective Action Guides (4) and by the International Commission on Radiological Protection (5,6).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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## National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in

milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program  
Radiostrontium in milk, HASL

Period reported  
July-December 1966

Last presented  
September 1967

### 1. Pasteurized Milk Network October 1967

*National Center for Radiological Health and  
National Center for Urban and Industrial  
Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN) was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal

Zone, Puerto Rico, and Washington, D.C. The most recent description of the sampling and analytical procedures employed by the PMN

**Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk**

Nuclide	Concentration (pCi/liter)	Error * (pCi/liter)	Concentration (pCi/liter)	Error * (percent of concentration)
Strontium-89-----	< 50	5	≥ 50	10
Strontium-90-----	< 20	2	≥ 20	10
Iodine-131-----	<100	10	≥100	10
Cesium-137-----	<100	10	≥100	10
Barium-140-----	<100	10	≥100	10

\* Two standard deviations.

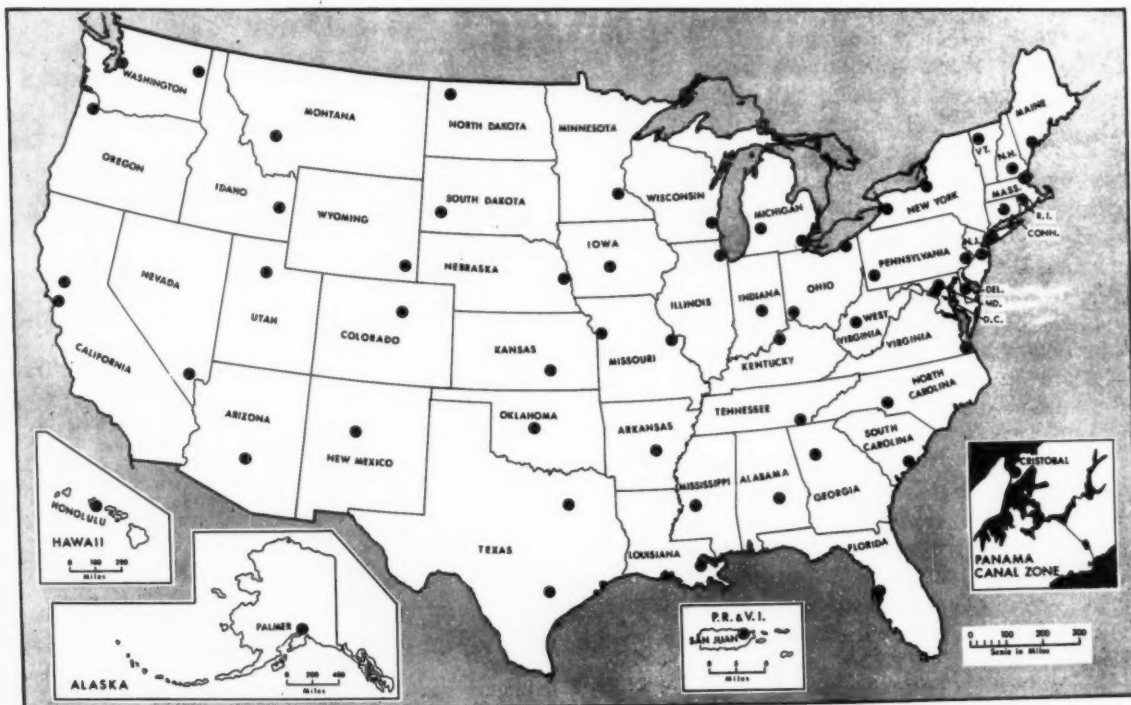


Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for October 1967 and the 12-month period, November 1966 through October 1967

Sample location		Radionuclide concentration (pCi/liter)									
		Strontium-89		Strontium-90		Cesium-137		Iodine-131		Barium-140	
		Nov. 1966 * Oct. 1967	Oct. 1967*	Nov. 1966- Oct. 1967	Oct. 1967	Nov. 1966- Oct. 1967	Oct. 1967	Nov. 1966- Oct. 1967	Oct. 1967	Nov. 1966- Oct. 1967	Oct. 1967
Ala:	Montgomery	0	0	10.4	8.4	16	17	2	0	0	0
Alaska:	Palmer	0	0	8.5	6.6	22	16	0	0	0	0
Aris:	Phoenix	0	0	1.6	1.4	2	0	0	0	0	0
Ark:	Little Rock	1	0	24.1	19.9	20	14	1	0	1	0
Calif:	Sacramento	2	0	3.3	2.7	4	0	2	0	0	0
	San Francisco	3	0	3.4	1.5	2	0	1	0	1	0
C. Z:	Cristobal	0	0	4.7	2.3	22	10	0	0	0	0
Colo:	Denver	0	0	6.3	5.1	5	3	1	0	0	0
Conn:	Hartford	0	0	9.4	8.0	20	14	1	0	0	0
Del:	Wilmington	0	0	11.5	9.8	16	7	1	0	0	0
D. C:	Washington	0	0	10.4	9.8	11	6	0	0	0	0
Fla:	Tampa	1	0	8.7	7.9	77	80	1	0	0	0
Ga:	Atlanta	0	0	15.7	13.5	25	21	3	0	0	0
Hawaii:	Honolulu	0	0	4.0	2.2	11	5	0	0	2	0
Idaho:	Idaho Falls	1	1	6.9	6.2	9	12	1	0	0	0
Ill:	Chicago	0	0	8.6	7.3	16	6	1	0	0	0
Ind:	Indianapolis	0	0	9.2	6.5	12	5	1	0	0	0
Iowa:	Des Moines	1	0	8.3	7.2	8	0	0	0	1	0
Kans:	Wichita	1	0	9.3	8.8	5	4	0	0	0	3
Ky:	Louisville	2	0	13.7	11.7	9	1	0	0	1	0
La:	New Orleans	1	0	25.4	21.8	30	24	1	0	1	0
Maine:	Portland	0	0	12.4	9.9	39	29	0	0	0	0
Md:	Baltimore	0	0	11.2	10.9	13	0	1	0	0	0
Mass:	Boston	0	0	12.5	10.3	33	24	0	0	0	0
Mich:	Detroit	0	0	9.2	8.4	16	5	1	0	0	0
	Grand Rapids	0	0	10.5	6.4	20	8	0	0	0	0
Minn:	Minneapolis	1	0	14.5	10.0	14	11	0	0	0	0
Miss:	Jackson	2	0	19.2	15.7	17	18	2	0	1	0
Mo:	Kansas City	1	0	10.0	9.1	4	4	1	0	1	5
	St. Louis	2	0	10.4	9.3	8	7	0	0	2	0
Mont:	Helena	1	0	7.4	5.4	11	11	0	0	0	0
Neb:	Omaha	0	0	9.2	3.4	6	2	1	0	0	0
Nev:	Las Vegas	0	0	1.9	1.4	2	0	0	0	0	0
N. H:	Manchester	0	0	14.8	9.3	46	31	0	0	0	0
N. J:	Trenton	0	0	10.0	9.6	17	11	0	0	0	0
N. Mex:	Albuquerque	0	0	3.5	1.5	2	2	0	0	0	0
N. Y:	Buffalo	0	0	8.6	7.8	17	4	0	0	1	0
	New York City	0	0	11.5	9.9	19	5	0	0	0	0
	Syracuse	0	0	9.3	10.2	20	14	1	0	0	0
N. C:	Charlotte	0	0	18.1	16.5	17	10	0	0	1	0
N. Dak:	Minot	3	3	15.9	10.9	15	6	0	0	1	0
Ohio:	Cincinnati	0	0	10.0	6.9	11	5	0	0	0	0
	Cleveland	0	0	10.3	8.8	16	0	1	0	0	0
Okl:	Oklahoma City	0	0	10.4	9.4	6	2	1	0	0	0
Ore:	Portland	2	0	8.5	7.0	15	12	2	0	0	0
Pa:	Philadelphia	0	0	10.2	9.3	13	0	1	0	0	0
	Pittsburgh	0	0	13.4	9.8	21	14	2	0	0	0
P. R:	San Juan	2	0	5.1	5.1	15	20	0	0	0	0
R. I:	Providence	0	0	11.5	10.5	27	17	0	0	0	0
S. C:	Charleston	0	0	16.9	14.4	32	33	4	0	0	0
S. Dak:	Rapid City	2	0	12.3	10.3	14	4	1	0	1	0
Tenn:	Chattanooga	0	0	16.8	16.4	17	11	1	0	1	0
	Memphis	0	0	13.8	12.5	5	3	1	0	0	0
Tex:	Austin	0	0	3.7	4.7	4	3	5	0	0	0
	Dallas	0	0	9.4	7.4	8	0	2	0	0	0
Utah:	Salt Lake City	1	0	7.3	5.7	10	6	1	0	1	4
Vt:	Burlington	0	0	10.8	8.2	21	10	1	0	0	0
Va:	Norfolk	1	0	12.9	12.1	11	6	1	0	1	1
Wash:	Seattle	2	0	11.3	8.7	30	25	0	0	0	2
	Spokane	0	0	10.5	6.7	21	18	0	0	0	0
W. Va:	Charleston	0	0	12.8	9.0	8	2	0	0	0	0
Wisc:	Milwaukee	0	0	7.7	6.3	16	8	0	0	0	0
Wyo:	Laramie	0	0	5.8	4.9	6	9	0	0	0	0
Network average		1	0	10.4	8.5	16	10	1	0	0	0

\* Blank indicates no strontium-90 determinations were made on samples from station during month.

appeared in the January 1968 issue of *Radiological Health Data and Reports* (1).

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly the minimum detectable concentrations in pCi/liter are: strontium-89, 5; strontium-90, 2; cesium-137, 10; barium-140, 10; iodine-131, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

In past issues, the presentation of data has included a table of average concentrations for the month and most recent quarter. Beginning with this issue, the quarterly average has been replaced by an annual average for the 12-month period ending with the month being reported.

This will facilitate evaluations of population exposure with respect to the guidance provided by the Federal Radiation Council, which suggests average total daily intakes averaged over periods of a year, as an appropriate criterion (2). Thus, table 2 contains averages for October 1967 and 12-month averages for the period November 1966 through October 1967.

The average radionuclide concentrations are based on results obtained from samples collected weekly. In previous reports these averages were rounded as follows prior to tabulation: strontium-90, nearest whole number; strontium-89 and cesium-137, nearest 5; iodine-131 and barium-140, nearest 10. Since the analytical error associated with the determination of these radionuclides in milk is presented in conjunction with the data, the rounding procedure has been discontinued and the averages are given to the same accuracy as the weekly concentrations reported by the laboratories, i.e., the nearest whole number for all the

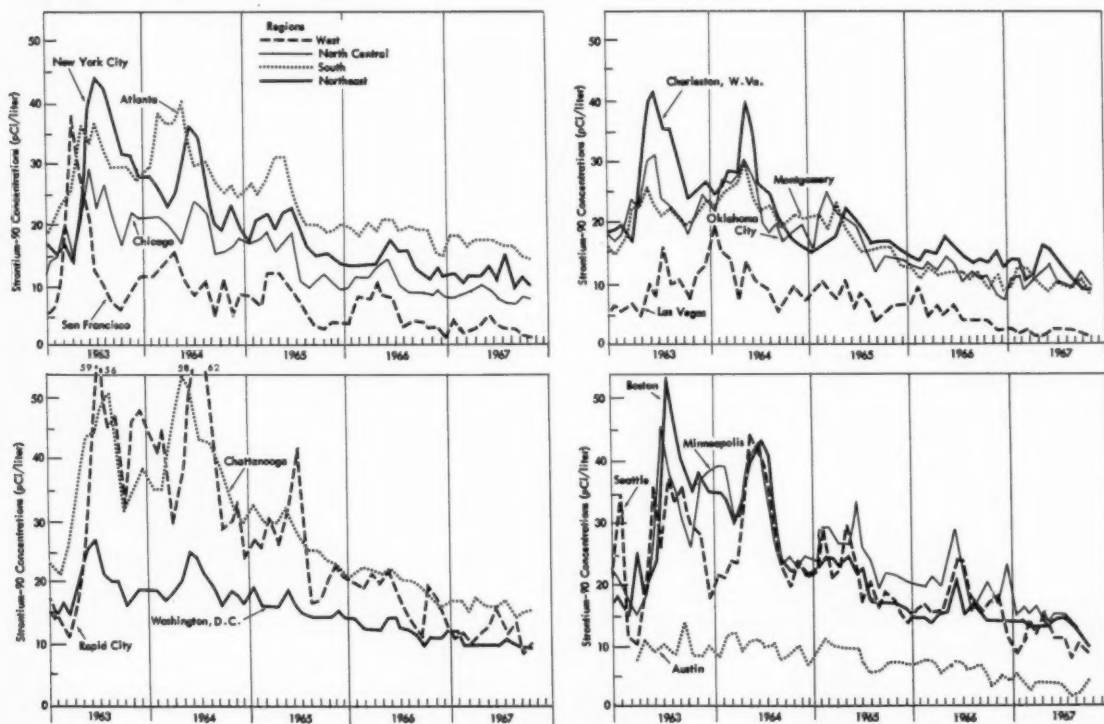


Figure 2. Strontium-90 concentrations in pasteurized milk, 1961-October 1967

radionuclides except strontium-90, which is reported to the nearest tenth.

Another change from past reports is in the interpretation for averaging purposes of weekly values below minimum detectable concentrations. For the sake of consistency, zero is now used for all the radionuclides, instead of only iodine-131 and barium-140, whenever concen-

**Table 3.** Frequency distribution, strontium-90 concentrations at PMN stations, October 1966 and May-October 1967

Strontium-90 (pCi/liter)	Number of stations						
	1966	1967					
	Oct.	May	June	July	Aug.	Sept.	Oct.
Under 10.....	18	25	27	25	35	37	46
10-19.....	39	35	34	35	26	24	16
20-29.....	6	3	2	3	2	2	1

trations are less than or equal to the appropriate minimum detectable levels.

For comparative purposes, distributions of strontium-90 and cesium-137 are presented in tables 3 and 4 for October 1966, and May through October 1967. The average strontium-90 concentrations in pasteurized milk from selected cities are presented in figure 2.

**Table 4.** Frequency distribution, cesium-137 concentrations at PMN stations, October 1966 and May-October 1967

Cesium-137 (pCi/liter)	Number of stations						
	1966	1967					
	Oct.	May	June	July	Aug.	Sept.	Oct.
Under 50.....	62	61	61	61	61	62	62
50-99.....	0	2	2	2	2	1	1
100-149.....	1	0	0	0	0	0	0

## 2. Canadian Milk Network October 1967<sup>1</sup>

*Radiation Protection Division  
Department of National Health and Welfare*

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered

milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

<sup>1</sup> Prepared from November 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.



**Figure 3.** Canadian milk sampling stations

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine-131, and monthly composites are analyzed for strontium-90, cesium-137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (3).

The October 1967 monthly average strontium-90, cesium-137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine-131 and strontium-89 concentrations were below minimum detectable levels.

Table 5. Stable elements and radionuclides in Canadian whole milk, October 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.19	1.5	9.4	14
Edmonton	1.12	1.5	8.1	24
Ft. William	1.08	1.6	14.7	30
Fredericton	1.08	1.5	16.1	23
Halifax	1.14	1.5	14.6	26
Montreal	1.08	1.5	9.8	16
Ottawa	1.12	1.6	8.6	14
Quebec	1.12	1.5	13.6	22
Regina	1.12	1.5	8.7	14
St. John's, Nfld.	1.12	1.5	20.6	34
Saskatoon	1.11	1.5	9.4	11
Sault Ste. Marie	1.10	1.5	16.5	31
Toronto	1.13	1.5	5.6	13
Vancouver	1.21	1.5	15.2	51
Windsor	1.11	1.5	4.4	11
Winnipeg	1.18	1.7	8.6	18
Average	1.13	1.5	11.5	22

### 3. Pan American Milk Sampling Program October 1967

*Pan American Health and Organization and  
U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (4).

Table 6 presents stable potassium, strontium-90 and cesium-137 monthly concentrations for October 1967.



Figure 4. Pan American Milk Sampling Program stations

Radiological Health Data and Reports

**Table 6. Stable element and radionuclide concentrations in PAHO milk, October 1967<sup>a</sup>**

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Colombia: Bogota	1	1.49	1	< 5
Chile: Santiago	1	1.53	<1	< 5
Ecuador: Guayaquil	1	1.61	<1	20
Jamaica: Kingston	1	1.46	5	85
Venezuela: Caracas	1	1.57	3	10
Canal Zone: Cristobal <sup>b</sup>	5	1.48	3	15
Puerto Rico: San Juan <sup>b</sup>	5	1.57	5	20

<sup>a</sup> Strontium-89 was less than 5 pCi/liter and iodine-131 and barium-140 were less than 10 pCi/liter for all samples.

<sup>b</sup> For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network, are presented.

## REFERENCES

- (1) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, September 1967. Radiol Health Data Rep 8:20-23 (January 1968).
- (2) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).
- (3) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702-703 (December 1966).
- (4) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704-705 (December 1966).

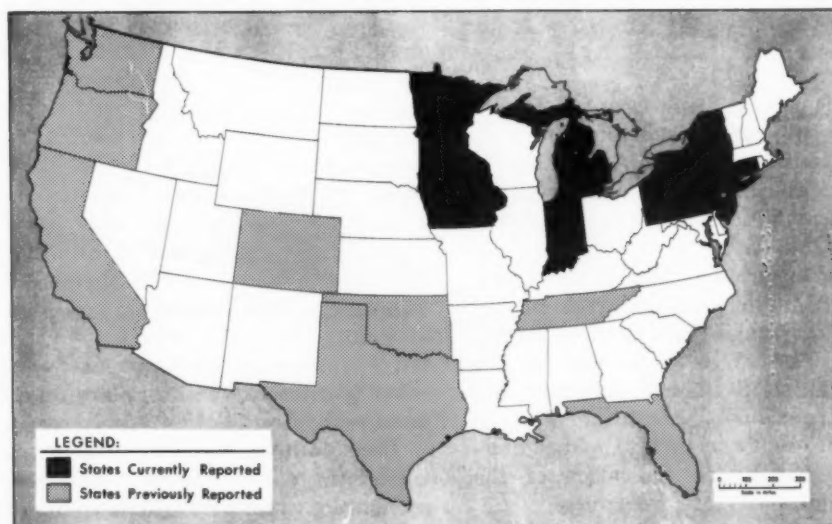
## State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk

surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows the States which report milk surveillance activities in *Radiological Health Data and Reports*. States having programs ap-



**Figure 1. Reported State milk programs**

pearing in the current issue are highlighted in the figure. A summary of State programs pre-

viously covered, the reporting period, and issue of appearance are as follows:

<u>State milk network</u>	<u>Period reported</u>	<u>Last presented</u>
California	April-June 1967	December 1967
Colorado	July-September 1967	January 1968
Florida	July-September 1967	January 1968
Oklahoma	July-September 1967	January 1968
Oregon	April-June 1967	December 1967
Tennessee	July-September 1967	January 1968
Texas	July-September 1967	January 1968
Washington	April-June 1967	December 1967

### 1. Connecticut Milk Network July-September 1967

*Connecticut State Department of Health*

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium-89 and strontium-90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 2). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium-89, strontium-90, and gamma-ray emitters. Concentrations of iodine-131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium-89 and strontium-90 are determined by chemical separation. Iodine-131 and

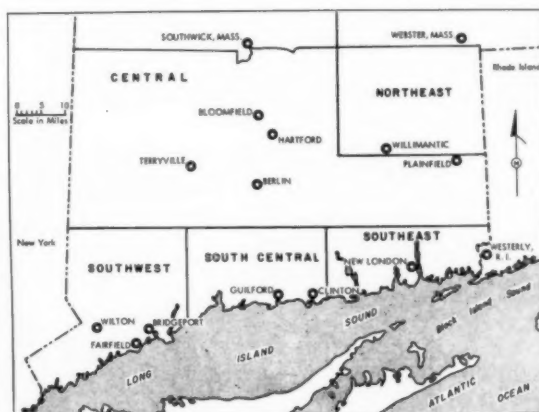


Figure 2. Connecticut pasteurized milk sampling stations

other gamma-ray emitters are determined by gamma-ray scintillation spectroscopy.

The monthly average concentrations of strontium-89, strontium-90, iodine-131, and cesium-137, in central Connecticut pasteurized milk are presented in table 1. These results are presented graphically in figure 2.

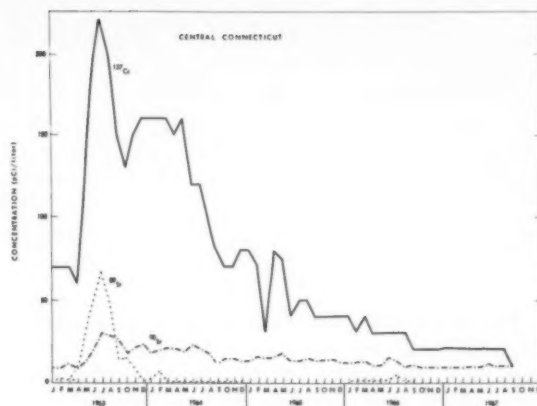
**Table 1. Radionuclide concentrations in central Connecticut pasteurized milk, July–September 1967**

Month	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
July	ND	10	ND	20
August	ND	10	ND	20
September	ND	10	ND	10

ND, below detectable levels.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–March 1967	August 1967
April–June 1967	November 1967



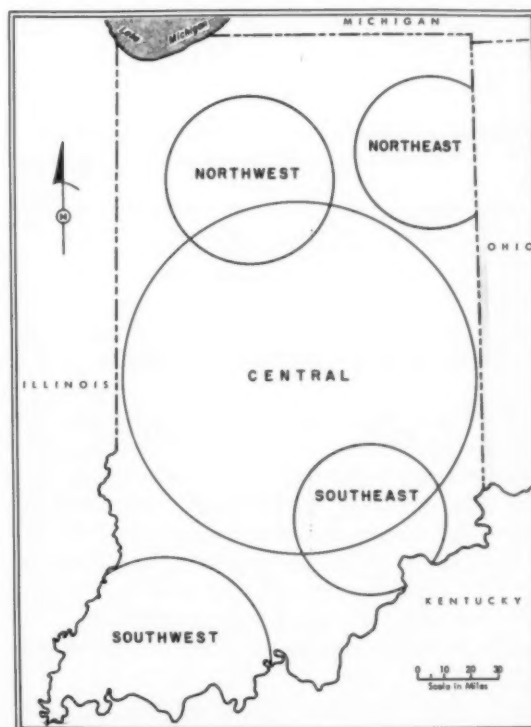
**Figure 3. Radionuclide concentrations in central Connecticut pasteurized milk, 1963–September 1967**

## 2. Indiana Milk Network July–September 1967

*Bureau of Environmental Sanitation  
Indiana State Board of Health*

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds; northeast, northwest, central, southeast, and southwest (figure 4). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium-89 and strontium-90. Cesium-137, iodine-131, and barium-140 are analyzed weekly for at least two of the milksheds. When iodine-131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.



**Figure 4. Indiana pasteurized milk sampling stations**

Table 2. Stable element and radionuclides in Indiana pasteurized milk, July-September 1967

Sampling location	Calcium (g/liter)			Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	July	August	Sept	July	August	Sept	July	August	Sept	July	August	Sept
Northeast.....	1.08	1.11	1.13	1,330	1,230	1,260	12	9	18	15	15	10
Southeast.....	1.15	1.13	1.17	1,430	1,260	1,360	13	11	11	20	15	20
Central.....	1.14	1.13	1.11	1,320	1,310	1,290	9	7	8	15	5	10
Southwest.....	1.15	1.16	1.11	1,380	1,250	1,240	10	12	12	10	10	15
Northwest.....	1.07	1.12	1.14	1,360	1,300	1,330	9	10	9	15	10	5
Average.....	1.12	1.13	1.13	1,360	1,270	1,300	11	10	12	15	11	12

Strontium-89 and strontium-90 concentrations in milk samples are determined by ion exchange separation (1,2) while cesium-137, iodine-131, and barium-140 are determined by gamma-ray scintillation spectrometry (3).

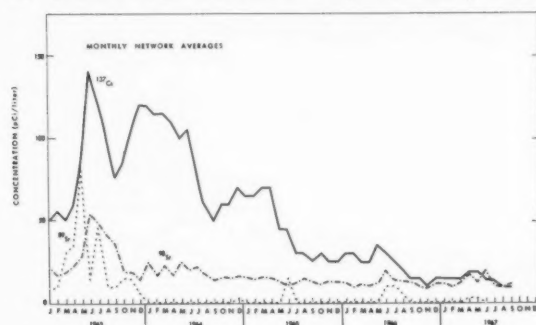


Figure 5. Radionuclide concentrations in Indiana pasteurized milk, 1961-September 1967

The monthly stable element and radionuclide concentrations in Indiana pasteurized milk are presented by sampling locations in table 2 for July through September 1967.

The monthly network average concentrations of strontium-89, strontium-90, and cesium-137 are presented graphically in figure 5. Barium-140 and iodine-131 concentrations remained below detectable levels of 10 pCi/liter and strontium-89 concentrations remained below detectable levels of 0.6 pCi/liter during this period.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-March 1967	August 1967
April-June 1967	November 1967

### 3. Iowa Milk Network July-September 1967

*State Hygienic Laboratory and the  
Iowa State Department of Health*

In Iowa, radiological health activities are conducted jointly by the State Department of Health and the State Hygienic Laboratory, with the State Hygienic Laboratory performing the surveillance and analytical functions.

In August 1962 the State Hygienic Laboratory of Iowa began sampling milk for iodine-131. In May 1964 this routine surveillance was expanded to include cesium-137 and strontium-90.

One gallon samples are collected from 4 stations, selected to give a broad coverage of milk production areas in the State (figure 6). Pro-

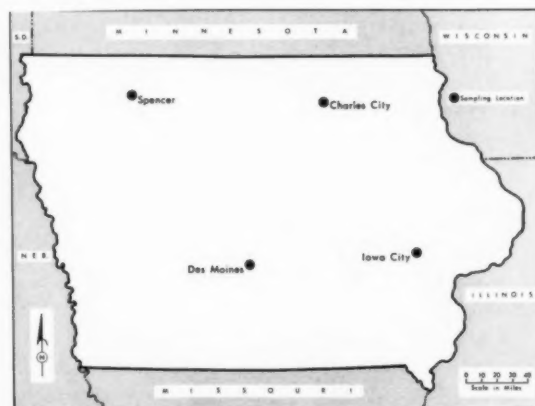


Figure 6. Iowa milk sampling stations

ducers furnishing milk to the Spencer bottling area are quite restricted to that northwest part of the State and the majority of milk bottled

in Iowa City comes from six counties in east central Iowa. The Des Moines milkshed comprises approximately 60 counties covering about two thirds of the State radiating out of Des Moines in all directions. The Charles City bottling area covers primarily north central Iowa. At present the Iowa City and Des Moines stations are sampled weekly and the Spencer and Charles City stations are sampled monthly. This sampling frequency is increased when nuclide concentrations warrant closer surveillance. The samples are forwarded to the State Hygienic Laboratory at the University of Iowa, Iowa City, for analysis.

#### Analytical procedures

Iodine-131 and cesium-137 together with barium-lanthanum-140 and potassium-40 are determined by gamma-scintillation spectrometry using a 4- by 4-inch NaI (Tl) crystal and 512 channel pulse-height analyzer. All samples are 3.5 liters and are counted for 80 minutes in Marinelli beakers with the results being calculated using a 4 by 4 matrix. Strontium-90 is determined by an ion-exchange system described by Porter, *et al* (4). One liter of milk is passed through an ion exchange column; yttrium-90 is eluted from the resin and counted as yttrium oxalate in an automatic low-background proportional counter. Minimum detectable limits are 10 pCi/liter for iodine-131 and cesium-137 and 2 pCi/liter for strontium-90.

#### Results

Table 3 gives the monthly averages at each of the four locations for July-September 1967 and figure 7 shows graphically the overall net-

work average monthly results for the same period. During this period it can be seen that the concentration levels of cesium-137 and strontium-90 showed a decreasing trend. Iodine-131 was only present to any significant amount during the month of June 1965.

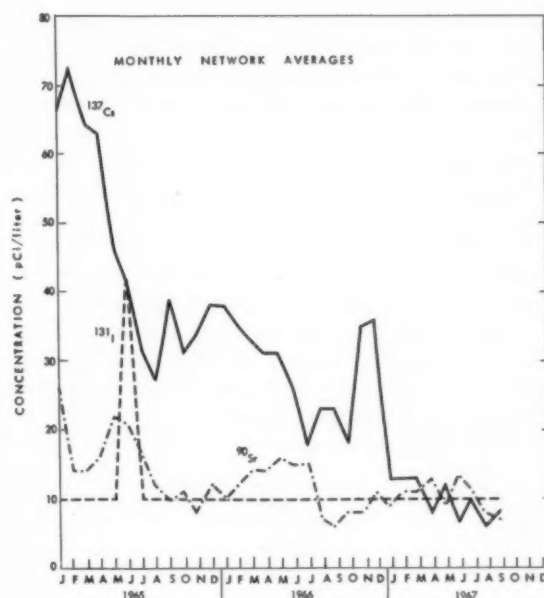


Figure 7. Radionuclide concentrations in Iowa milk January 1965-September 1967

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-March 1967	August 1967
April-June 1967	November 1967

Table 3. Radionuclide concentrations in Iowa milk, July-September 1967

Sampling location	Radionuclide concentration (pCi/liter)								
	Strontium-90			Cesium-137			Iodine-131		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Iowa City.....	9	9	8	<10	<10	<10	<10	<10	<10
Des Moines.....	9	10	5	<10	<10	<10	<10	<10	<10
Spencer.....	14	6	8	11	<10	<10	<10	<10	<10
Charles City.....	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average.....	11	8	7	<10	<10	<10	<10	<10	<10

NA, no analysis.

#### 4. Michigan Milk Network July–September 1967

*Division of Occupational Health  
Michigan Department of Health*

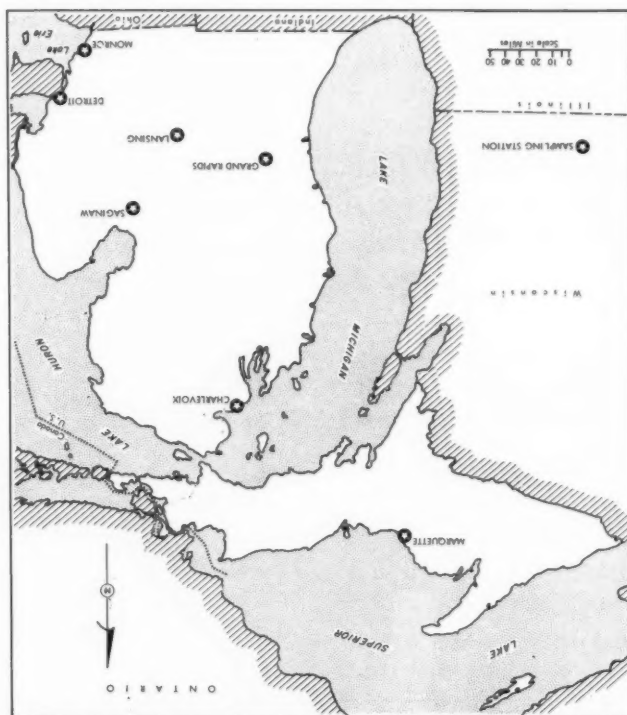
The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 8). Milkshed samples are composites from dairies in proportion to sales volumes.

Strontium-90 concentrations are determined by an ion exchange method (5). Potassium-40, iodine-131, cesium-137, and barium-lanthanum-140 concentrations are determined by gamma-ray scintillation spectrometry (5).

Table 5 presents the monthly average radionuclide concentrations in Michigan pasteurized milk. Strontium-90 and cesium-137 concentrations are presented graphically in figure 9 to show general trends.

**Table 5. Radionuclide concentration in Michigan pasteurized milk, July–September 1967**

Sampling location	Month	Radionuclide concentrations (pCi/liter)			
		Potassium-40	Strontium-90	Iodine-131	Cesium-137
Charlevoix	July	1,350	6	<14	13
	August	1,360	4	<14	12
	September	1,360	4	<14	9
Detroit	July	1,320	5	<14	9
	August	1,340	4	<14	7
	September	1,320	4	<14	7
Grand Rapids	July	1,280	5	<14	15
	August	1,330	5	<14	10
	September	1,320	3	<14	10
Lansing	July	1,330	6	<14	10
	August	1,350	4	<14	10
	September	1,290	3	<14	6
Marquette	July	1,320	10	<14	37
	August	1,330	9	<14	33
	September	1,310	8	<14	24
Monroe	July	1,360	4	<14	7
	August	1,300	3	<14	5
	September	1,330	3	<14	7
Saginaw	July	1,330	5	<14	11
	August	1,290	3	<14	8
	September	1,340	2	<14	7
Average	July	1,330	6	<14	15
	August	1,330	5	<14	12
	September	1,320	4	<14	10



**Figure 8. Michigan pasteurized milk network sampling stations**

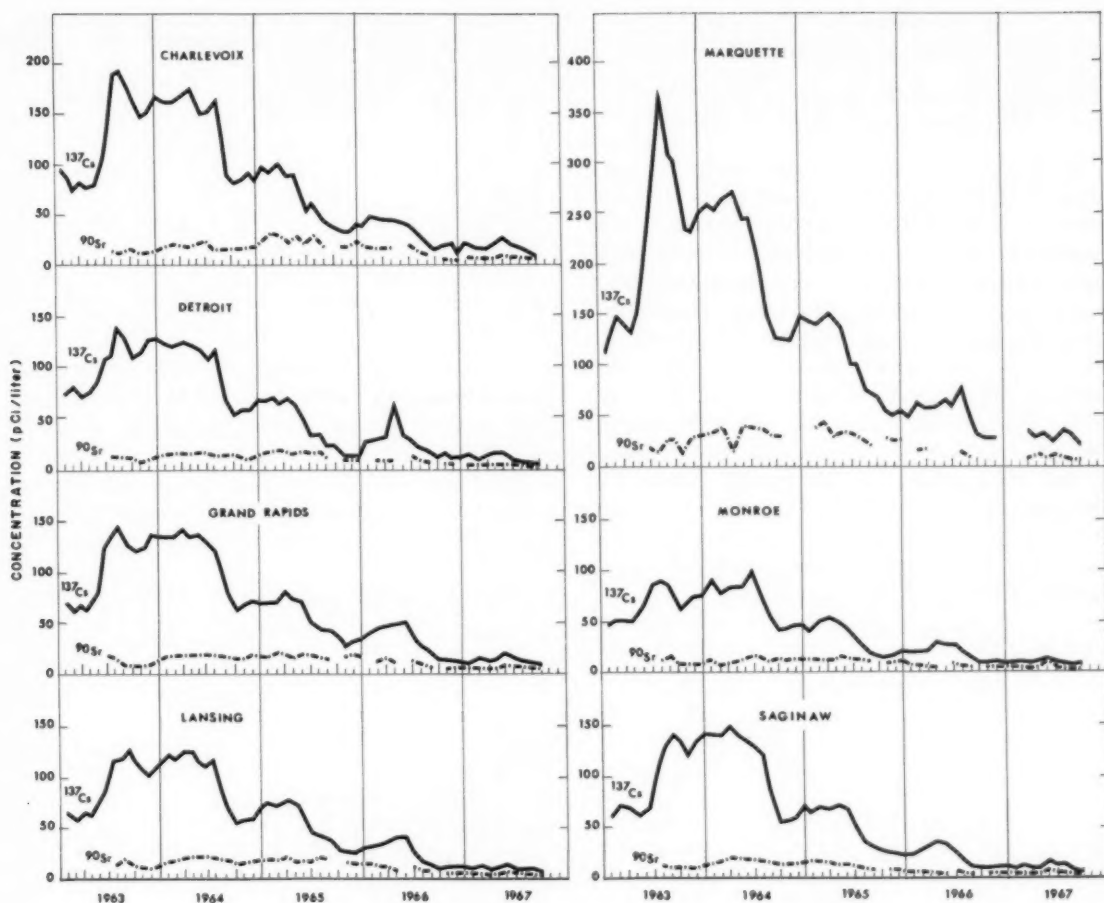


Figure 9. Radionuclide concentrations in Michigan pasteurized milk  
1963–September 1967

Recent coverage in *Radiological Health Data and Reports*:

Period

January 1965–March 1967  
April–June 1967

Issue

August 1967  
November 1967

## 5. Minnesota Milk Network July–September 1967

*Division of Environmental Health  
Minnesota Department of Health*

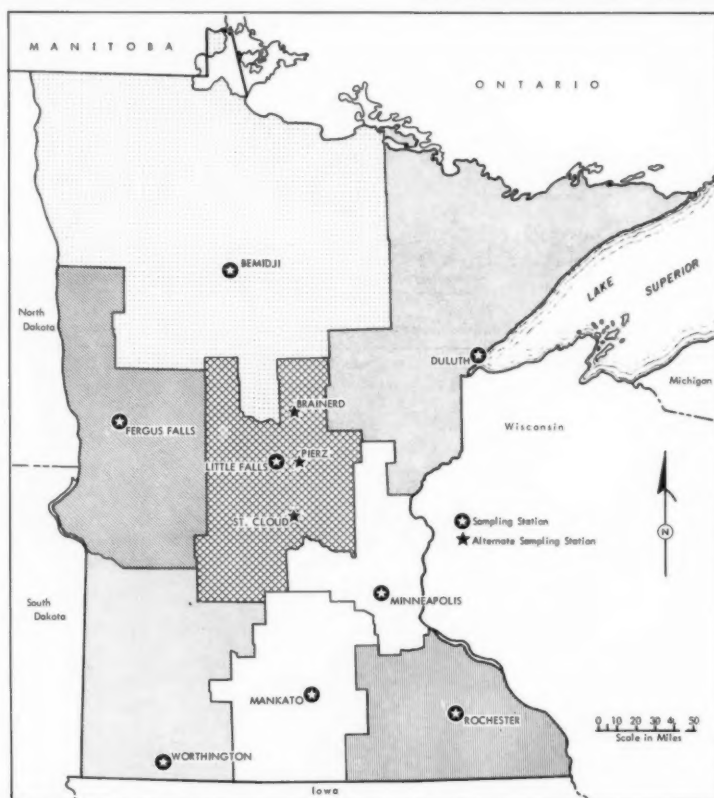
In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium-90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 10) and analyzed for strontium-90; iodine-131, and cesium-137. One liter samples of processed Grade A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health Department district offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned.

**Table 6. Radionuclide concentrations in Minnesota pasteurized milk July–September 1967**

Location	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	July	Aug	Sept	July	Aug	Sept
Bemidji.....	14	16	14	29	38	19
Mankato.....	12	6	6	14	7	3
Rochester.....	9	8	8	6	7	8
Duluth.....	24	18	17	42	49	24
Worthington.....	9	7	6	14	4	8
Minneapolis.....	16	14	12	20	19	13
Fergus Falls.....	11	8	8	17	4	13
Little Falls.....	12	12	9	19	15	15
Average.....	13	11	10	20	18	13

Strontium-90 concentrations are determined radiochemically while iodine-131 and cesium-137 concentrations are determined by gamma-ray scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (6).

Strontium-90 and cesium-137 concentra-



**Figure 10. Minnesota milk sampling stations**

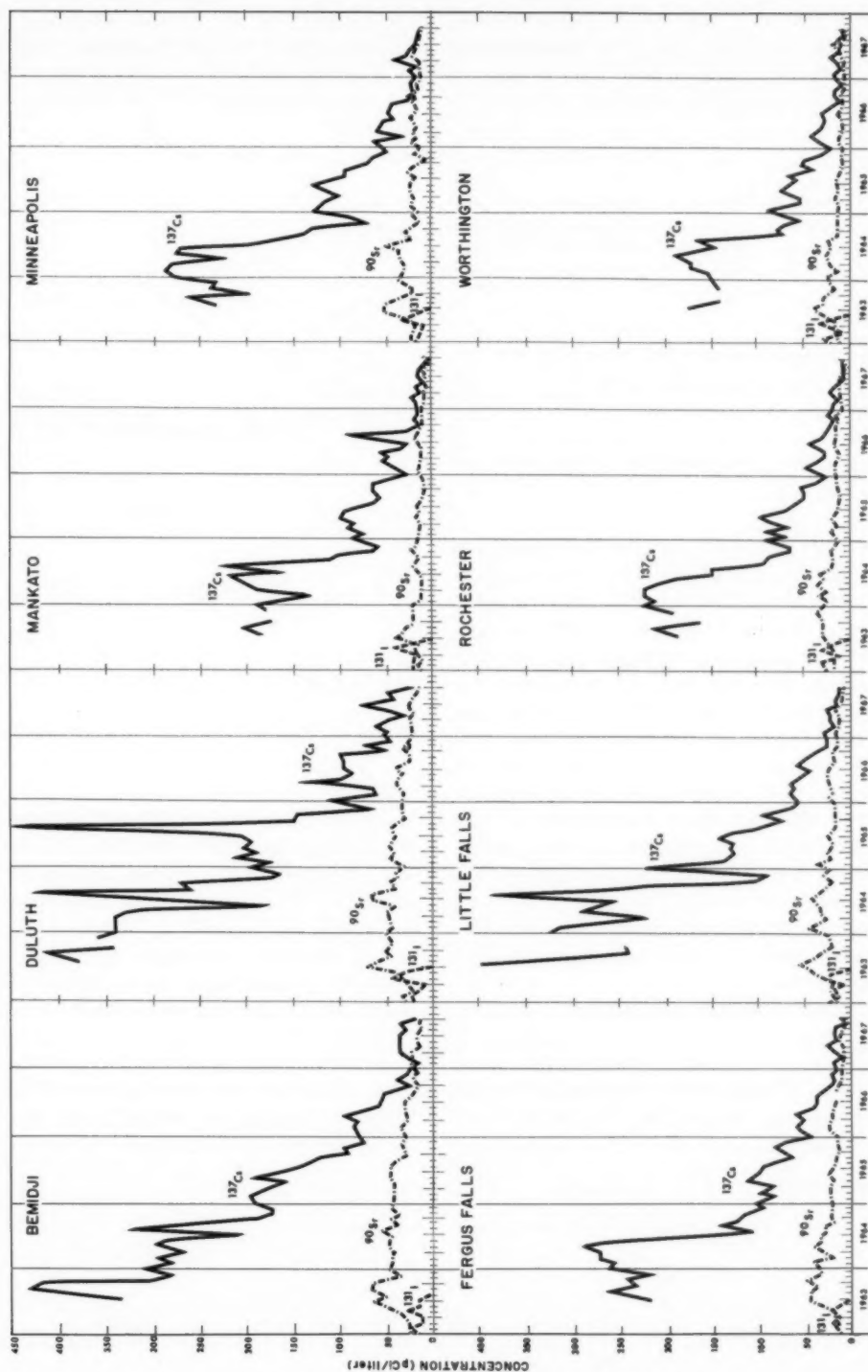


Figure 11. Radionuclide concentrations in Minnesota milk, 1963-September 1967

tions in milk are given for July through September 1967, in table 6 and are presented graphically by milkshed in figure 11 for the

period 1961 through September 1967. Iodine-131 concentrations were less than 10 pCi/liter in all 24 samples.

Recent coverage in *Radiological Health Data and Reports*:

Period  
January-March 1967  
April-June 1967

Issue  
August 1967  
November 1967

## 6. Pennsylvania Milk Network July-September 1967

*Bureau of Environmental Health  
Pennsylvania Department of Health*

Samples of pasteurized milk are routinely collected from six major milk consumption areas throughout Pennsylvania (figure 14). Samples are collected weekly in Pittsburgh, while biweekly composite samples are collected from the other five stations. At each sampling location, subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the samples are analyzed for iodine-131, potassium-40, and cesium-137 and then composited for a monthly analysis of strontium-90. Strontium-90 analysis has been carried out since April 1963.

The monthly average potassium-40, stron-

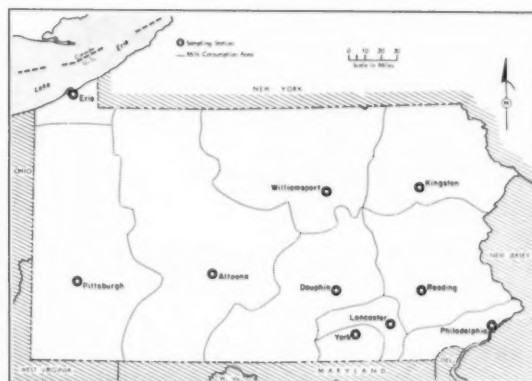


Figure 12. Pennsylvania milk network sampling stations

tium-90, iodine-131, and cesium-137 concentrations in pasteurized milk are given in table 7. For comparative purposes, strontium-90, iodine-131, and cesium-137 concentrations are presented graphically in figure 15.

The chemical separation technique for strontium-90 is essentially an ion-exchange method described by Porter, *et al* (2).

Table 7. Radionuclide concentrations in Pennsylvania pasteurized milk July-September 1967

Sampling location	Radionuclide concentrations (pCi/liter)											
	Potassium-40			Strontium-90			Iodine-131			Cesium-137		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Altoona	NS	1,410	1,380	NS	9	11	NS	<10	<10	NS	14	15
Dauphin	1,290	1,360	1,310	11	9	9	<10	<10	<10	14	17	11
Erie	1,350	1,425	1,390	11	13	10	<10	<10	10	27	19	17
Philadelphia	1,410	1,260	1,320	9	10	10	<10	<10	<10	15	14	17
Pittsburgh	1,330	1,390	1,490	11	13	13	<10	<10	<10	21	15	13
York	1,390	NS	NS	10	NS	NS	<10	NS	NS	16	NS	NS
Average	1,360	1,375	1,375	10	11	11	<10	<10	<10	19	16	15

NS, no sample.

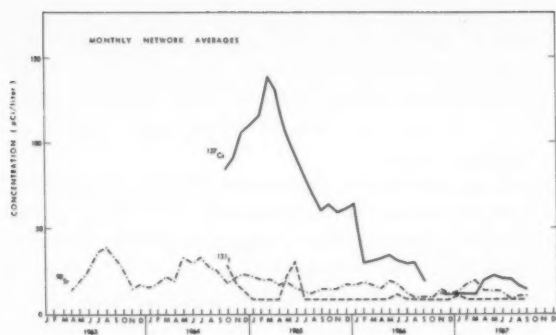


Figure 13. Radionuclide concentrations in Pennsylvania milk, 1963–September 1967

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–March 1967	August 1967
April–June 1967	November 1967

## REFERENCES

- (1) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determination of strontium-90 in milk by an ion-exchange method. *Anal Chem* 33:1306–1308 (September 1961).
- (2) PORTER, C. and B. KAHN. Improved determinations of strontium-90 in milk by an ion-exchange method. *Anal Chem* 36:676–678 (March 1964).
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- (4) PORTER, C., R. AUGUSTINE, J. MATUSEK, JR., and M. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples, PHS Publication No. 999–RH–10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).
- (5) MICHIGAN DEPARTMENT OF HEALTH. Michigan milk network, November 1962–December 1964. *Radiol Health Data* 6:487–492 (September 1965).
- (6) MINNESOTA DEPARTMENT OF HEALTH AND RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January–June 1965, COO-615-17 (August 1965).

## Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for devel-

oping estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Last presented
Connecticut Standard Diet	January–June 1967	November 1967
Tri-City Diet, HASL	August–December 1966	September 1967
Institutional Diet, PHS	April–June 1967	January 1968

**1. Estimated daily intake of radionuclides in  
California diets  
March-June 1967**

*Bureau of Radiological Health  
California State Department of Public Health*

Since January 1964, the Bureau of Radiological Health, California State Department of Public Health, has made estimates of radionuclide levels in the diets of Californians (1).

Recognizing that a "standard" or "typical" diet does not exist due to variations in individ-

ual tastes, an effort was made to select a diet which was reasonably representative of the food consumed in a given area. This objective was met by utilizing the "house" diet of a hospital in each of the 20 geographic areas of interest (figure 1).

Hospitals were chosen as the source of diet samples under the hypothesis that their diets are as "reasonably representative" as any other. General hospitals exist in each of the 20 selected geographic areas and operate with trained dietitians. There is good reason to believe that hospitals utilize foods which are



Figure 1. California diet sampling stations

marketed in their respective communities. Also, working relations for entry into hospitals existed through the State Bureau of Nutrition and Hospitals.

#### Sampling procedure

In general, the sampling procedure is the same at each hospital. Samples are collected every 2 months at each facility. Each sample represents the edible portion of a regular meal (the standard diet) for a full 7-day week (21 consecutive meals).

After each sample is collected, it is suitably preserved and shipped to the Sanitation and Radiation Laboratory of the State Department of Public Health. Accompanying each sample is a record prepared by the dietitians indicating the types and quantities of food included.

#### Analytical procedures

After weighing at the laboratory, each sample is homogenized and analyzed for gamma-ray

emitters, then dried and ashed prior to analysis for strontium-89, strontium-90, radium-226, and stable calcium, strontium and sodium.

#### Data and discussion

The resultant estimates of daily intake of radionuclides in the California diets are given in table 1 (March-April 1967) and table 2 (May-June 1967).

It should be noted that levels of radioactivity were observed to be far below those levels for which consideration should be given to protective health action. A summary of strontium-90 and cesium-137 intake trends in California diets from January 1964 through June 1967 is given in figures 2 and 3.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-April 1966	January 1967
May-August 1966	May 1967
September 1966-February 1967	October 1967

Table 1. Estimated daily intake of radionuclides in California diets, March-April 1967<sup>a</sup>

City	Consumption (kg/capita • day) <sup>b</sup>	Intake (pCi/capita • day)							Intake (g/capita • day)			
		<sup>90</sup> Sr	<sup>89</sup> Sr	<sup>226</sup> Ra	<sup>137</sup> Cs	<sup>90</sup> Zr	<sup>54</sup> Mn	<sup>137</sup> Cs <sup>144</sup> Ce	K <sup>c</sup>	Na	Ca	Stable strontium
Bakersfield.....	2.1	0	5	0.7	9	1	0	0	2.0	3.1	0.9	0.003
Berkeley.....	2.2	#2	4	0.9	26	0	0	0	2.1	3.1	0.8	.003
Bishop.....	1.7	#2	5	0.7	11	4	0	0	2.4	3.0	0.7	.002
Brawley.....	1.8	3	5	0.9	9	0	0	0	2.0	3.0	0.6	.003
Crescent City.....	2.0	13	12	0.9	24	7	0	0	2.3	4.1	0.9	.003
Eureka.....	2.2	0	7	0.8	21	7	0	0	2.1	4.7	0.7	.004
Fresno.....	2.2	#1	5	1.2	16	1	0	0	2.0	3.2	0.6	.002
Los Angeles (Santa Monica).....	1.9	#3	9	0.8	13	2	0	0	2.2	3.7	0.7	.004
Needles.....	2.2	0	5	1.1	14	3	0	0	2.3	3.7	0.7	.004
Quincy.....	2.4	0	10	0.8	17	1	0	0	2.8	4.0	0.8	.002
Redding.....	2.2	#2	9	1.6	20	3	0	0	2.8	4.4	0.8	.003
Sacramento.....	2.4	6	9	1.4	18	2	0	0	2.3	4.0	1.3	.003
Salinas.....	2.3	7	3	1.4	15	0	0	0	2.6	5.1	0.7	.004
San Bernardino.....	1.6	0	7	0.1	6	2	0	0	1.9	3.0	0.8	.002
San Diego.....	(*)											
San Luis Obispo.....	1.3	#2	6	0.6	11	1	0	0	1.6	3.8	0.8	.003
Santa Barbara.....	2.1	#4	5	0.9	11	3	0	0	2.3	3.4	0.9	.004
Santa Rosa.....	1.7	4	7	0.6	13	1	2	0	1.7	2.3	1.0	.003
Susanville.....	1.9	#1	5	0.5	20	1	0	0	2.1	3.6	0.7	.003
Ukiah.....	2.5	0	4	1.1	18	0	0	0	2.1	4.0	1.0	.003

<sup>a</sup> Based on analyses of Hospital Standard Diets located in listed cities.

<sup>b</sup> Kilograms of food per person per day in this diet.

<sup>c</sup> Natural potassium contains 0.0119 percent radioactive potassium-40.

<sup>d</sup> When the counting rate of the sample is not equal to at least twice the 0.95 error the value reported is the best available estimate but is not statistically significant.

<sup>e</sup> Sample lost.

Table 2. Estimated daily intake of radionuclides in California diets, May-June 1967<sup>a</sup>

City	Consumption (kg/capita • day) <sup>b</sup>	Intake (pCi/capita • day)								Intake (g/capita • day)			
		<sup>90</sup> Sr	<sup>90</sup> Sr	<sup>226</sup> Ra	<sup>232</sup> Th	<sup>137</sup> Cs	<sup>134</sup> Cs	<sup>134</sup> Cs	<sup>134</sup> Cs	K <sup>40</sup>	Na	Ca	Stable strontium
Bakersfield.....	2.1	43	4	1.1	12	13	2	0	0	2.6	4.0	1.1	0.004
Berkeley.....	1.6	42	4	0.5	11	0	1	0	0.2	1.5	2.2	0.4	.003
Bishop.....	2.4	43	6	0.7	16	0	5	0	0	3.0	3.7	0.7	.004
Brawley.....	1.8	41	5	1.3	12	37	0	0	0	1.6	3.1	NA	.003
Crescent City.....	2.1	9	12	0.8	23	0	4	0	0	2.8	3.3	0.8	.005
Eureka.....	2.1	3	8	0.6	9	0	3	0	0	2.3	4.2	0.6	.004
Fresno.....	2.3	43	5	1.5	20	0	0	0	0	2.0	2.6	0.7	.003
Los Angeles.....	2.4	42	9	1.3	21	0	6	0	0	2.5	4.4	1.2	.005
Needles.....	2.5	41	6	1.6	14	4	3	0	0	2.5	3.4	1.0	.006
Quincy.....	2.2	42	8	0.7	12	0	4	0	0	2.5	3.0	1.0	.003
Redding.....	2.3	42	8	1.6	19	0	4	0	0	2.6	3.4	0.8	.003
Sacramento.....	2.5	41	9	1.4	25	72	0	0	0	2.8	5.0	NA	.001
Salinas.....	2.3	44	5	1.2	17	0	4	0	0	2.5	5.5	0.6	.004
San Bernardino.....	1.7	3	2	1.0	15	0	0	0	0	2.0	2.9	0.6	.004
San Diego.....	1.6	2	3	0.4	22	0	0	0	0	1.4	2.4	0.5	.003
San Luis Obispo.....	1.2	42	5	1.1	10	1	2	0	0	1.6	3.2	0.7	.003
Santa Barbara.....	2.0	43	5	0.8	8	0	4	0	0	3.0	4.4	1.1	.007
Santa Rosa.....	1.9	42	5	1.0	7	0	2	0	0	1.7	2.6	0.8	.004
Susanville.....	1.9	3	5	0.6	14	0	3	0	0	2.7	2.6	0.6	.004
Ukiah.....	2.3	8	9	1.0	20	11	1	0	0	2.3	4.2	1.3	.004

<sup>a</sup> Based on analyses of Hospital Standard Diets located in listed cities.<sup>b</sup> Kilograms of food per person per day in this diet.<sup>c</sup> Natural potassium contains 0.0119 percent radioactive potassium-40.<sup>d</sup> When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant.

NA, no analysis.

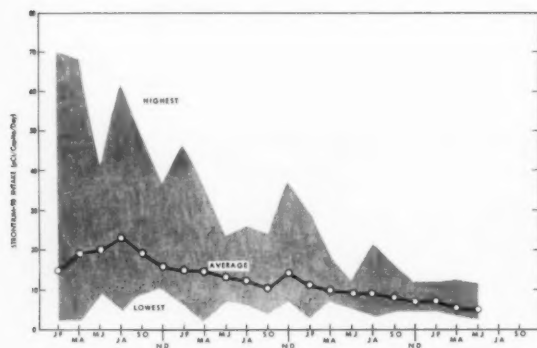


Figure 2. Averages and ranges of daily strontium-90 intake in California diets, 1964-June 1967

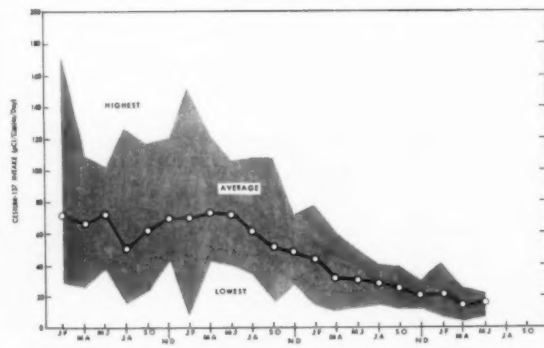


Figure 3. Averages and ranges of daily cesium-137 intake in California diets, 1964-June 1967

## REFERENCE

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## SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (1). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2-4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively.

Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence<sup>1</sup> of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

<sup>1</sup> Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Activity	Period reported	Last presented
Coast Guard Water Sampling Program	January-December 1966	November 1967
Minnesota Municipal Water	January-June 1967	January 1968
New York Surface Water	January-June 1966	September 1967
Radiostrontium in Tap Water, HASL	July-December 1966	November 1967
Washington Surface Water Sampling	July 1965-June 1966	August 1967

### REFERENCES

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- (2) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

- (3) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).
- (4) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

## Gross Radioactivity in Surface Waters of the United States, August 1967

Division of Pollution Surveillance, Federal  
Water Pollution Control Administration,  
Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium-90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the

sampling and analytical procedures was published in the August 1967 issue of *Radiological Health Data and Reports*.

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (1-6). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radio-

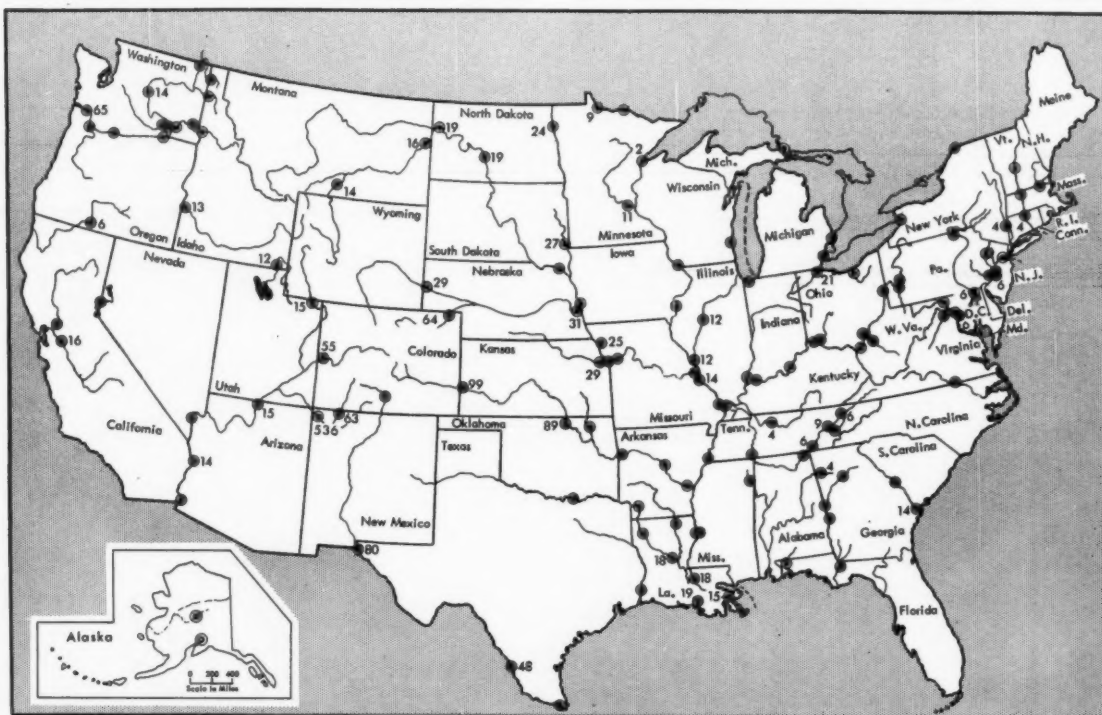


Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, August 1967

Table 1. Radioactivity in raw surface waters, August 1967

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)			Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:							Mississippi River:						
Cedar Hill, N. Mex.	16	2	18	54	9	63	St. Paul, Minn.	1	5	6	1	10	11
Arkansas River:							E. St. Louis, Ill.	2	1	3	3	11	14
Coolidge, Kans.	30	15	45	64	35	99	New Roads, La.	4	2	6	8	10	18
Ponca City, Okla.	8	7	15	73	16	89	New Orleans, La.	1	3	4	7	8	15
Atchafalaya River:							Missouri River:						
Morgan City, La.	3	3	6	12	7	19	Williston, N. Dak.	3	4	7	8	11	19
Bear River:							Bismarck, N. Dak.	1	4	5	4	15	19
Preston, Idaho.	1	4	5	0	12	12	St. Joseph, Mo.	3	4	7	10	15	25
Big Horn River:							North Platte River:						
Hardin, Mont.	1	2	3	1	13	14	Henry, Nebr.	3	12	15	7	21	29
Big Sioux River:							Ohio River:						
Sioux Falls, S. Dak.	2	4	6	5	22	27	Cairo, Ill.	0	2	2	2	5	7
Clinch River:							Platte River:						
Clinton, Tenn.	1	0	1	3	3	6	Plattsmouth, Nebr.	4	6	10	10	21	31
Kingston, Tenn.	0	<1	<1	1	8	9	Potomac River:						
Colorado River:							Washington, D. C.	0	1	1	1	5	6
Loma, Colo.	12	6	18	34	21	55	Rainy River:						
Page, Ariz.	0	6	6	<1	15	15	Baudette, Minn.	0	0	0	1	8	9
Parker Dam, Calif.-Ariz.	0	3	3	0	14	14	Red River, North:						
Columbia River:							Grand Forks, N. Dak.	1	4	5	2	22	24
Wenatchee, Wash.	0	7	7	0	14	14	Red River, South:	1	4	5	2	16	18
Clatskanie, Ore.	<1	0	<1	18	47	65	Alexandria, La.	1	4	5	2	16	18
Connecticut River:							Rio Grande:						
Enfield Dam, Conn.	0	0	0	1	3	4	El Paso, Tex.	19	3	22	67	13	80
Cocosa River:							Laredo, Tex.	10	3	13	38	10	48
Rome, Ga.	<1	0	<1	2	2	4	San Joaquin River:						
Cumberland River:							Vernalis, Calif.	3	2	5	9	7	16
Cheatham Lock, Tenn.	1	0	1	1	3	4	San Juan River:						
Delaware River:							Shiprock, N. Mex.	239	4	243	517	19	536
Philadelphia, Pa.	0	1	1	2	4	6	Savannah River:						
Great Lakes:							Port Wentworth, Ga.	<1	1	1	4	10	14
Duluth, Minn.	1	1	2	0	2	2	Snake River:						
Green River:							Payette, Idaho.	1	5	6	5	8	13
Dutch John, Utah.	<1	5	5	0	15	15	South Platte River:						
Hudson River:							Julesburg, Colo.	2	21	23	6	58	64
Poughkeepsie, N. Y.	0	1	1	0	4	4	Susquehanna River:						
Illinois River:							Conowingo, Md.	1	1	2	2	4	6
Peoria, Ill.	1	7	8	3	9	12	Tennessee River:						
Grafton, Ill.	1	4	5	3	9	12	Chattanooga, Tenn.	1	<1	1	2	4	6
Kansas River:							Yellowstone River:						
DeSoto, Kans.	4	4	8	14	15	29	Sidney, Mont.	2	3	5	5	11	16
Klamath River:							Maximum	239	21	243	517	58	536
Keno, Ore.	0	0	0	<1	6	6	Minimum	0	0	0	0	2	2
Maumee River:													
Toledo, Ohio	1	3	4	2	19	21							

\* Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

activity per unit weight of solids. A discussion of gross radioactivity per gram of solids for all stations of the Water Pollution Surveillance System for 1961 through 1965 has been presented (7). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During July and August, the following stations showed values in excess of 15 pCi/liter on alpha radioactivity for either suspended or dissolved solids:

San Juan River; Shiprock, N. Mex.  
South Platte River; Julesburg, Colo.

#### Arkansas River; Coolidge, Kans.

During August, Cedar Hill, N. Mex. on the Animas River and El Paso, Tex., on the Rio Grande showed values in excess of 15 pCi/liter on alpha radioactivity for suspended solids.

The following stations decreased to less than 15 pCi/liter on alpha radioactivity for either suspended or dissolved solids:

Rio Grande; Laredo, Tex.

Yellowstone River; Sidney, Mont.

Shiprock, N. Mex., on the San Juan River showed a suspended beta radioactivity in excess of 150 pCi/liter. This high value is due to a correspondingly high level of suspended solids.

## REFERENCES

- (1) PUBLIC HEALTH SERVICE. DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
- (2) *Ibid.*, 1959 Edition.
- (3) *Ibid.*, 1960 Edition.
- (4) *Ibid.*, 1961 Edition.
- (5) *Ibid.*, 1962 Edition.
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- (7) JULIAN, E. C. Gross radioactivity of the solids in selected surface waters of the United States, 1961-1965. Radiol Health Data Rep 9:1-12 (January 1968).

## Radioactivity in California Waters<sup>1</sup>, July-December 1966

*Bureau of Radiological Health,  
State of California  
Department of Public Health*

Gross beta radioactivity in California domestic waters is monitored by the State of California's Bureau of Radiological Health. The importance of this program in the State's environmental surveillance activities, stems from the fact that most of California's domestic water supplies are of surface origin.

Radioactivity in such water supplies consists of the natural radioactivity in surface streams, radioactivity added by the discharge of sewage or by industrial waste effluents, and radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Present efforts consist of sampling raw and treated surface waters and well waters. It should be noted that except for large metropolitan water supplies, raw water sampling is being phased out and treated water sampling substituted or continued. This procedural change is predicated upon sampling water at the point of consumption.

<sup>1</sup> Data from January and April 1967 issues of Radiological Health News, State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley, Calif. 94704.

Most of the supplies sampled have, as a source, raw surface waters (figure 1), although a few wells, along with some water supplies that use infiltration galleries, are also sampled.

Monitoring of domestic water supplies is on a continuing basis, since it has not been possible to forecast levels of radioactivity in these supplies based upon levels in rain, snow, or surface streams. Under the present sampling schedule, monthly 500 ml samples are collected and the total solids analyzed for alpha and beta radioactivity. In addition, 3-liter samples are collected monthly for approximately 6 months and composited for specific radionuclide analysis on a semiannual basis.

### *Analytical procedures*

Radionuclide analyses of water are carried out in the State's Sanitation and Radiation Laboratory. Measurements of alpha and alpha-plus-beta radioactivities are made with a low-background windowless gas-flow proportional counter. Counting methods used follow those recommended by the U.S. Public Health Service (1).



Figure 2. California surface water sampling stations

Individual samples are evaporated to dryness and the residue ashed at 450°C. The ashed sample is dissolved and transferred to an aluminum planchet for beta-particle counting. Radioisotopic analyses are determined semiannually on composite samples. Gamma-ray emitting nuclides are determined by gamma-ray spectroscopy and radium and radiostrontium by chemical separation and counting.

#### Discussion

Table 1 shows the monthly average beta

radioactivity in the suspended-plus-dissolved solids in surface water supplies in California from July through December 1966. Following treatment, these waters are used for industrial and domestic purposes. Because alpha radioactivity in water has, in general, been undetectable or very slight, alpha radioactivity analyses are not presented. No increase in radioactivity level of surface water has been observed.

Table 2 shows specific radionuclide concentrations in California surface waters for 1965 through June 1966 by stations.

Table 1. Gross beta radioactivity in California domestic waters, July-December 1966

Sampling station	Quality	Concentration (pCi/liter)					
		July	August	September	October	November	December
Alturas.....	Well	NS	NS	NS	NS	<sup>a</sup> 16	NS
Antioch.....	Treated	<sup>a</sup> 9	<sup>a</sup> 1	ND	<sup>a</sup> 5	32	<sup>a</sup> 2
Lake Arrowhead.....	Treated	NS	<sup>a</sup> 13	<sup>a</sup> 10	<sup>a</sup> 1	<sup>a</sup> 2	NS
Berkeley.....	Treated	ND	ND	<sup>a</sup> 9	<sup>a</sup> 3	<sup>a</sup> 11	<sup>a</sup> 17
Clearlake Highlands.....	Treated	<sup>a</sup> 3	<sup>a</sup> 9	<sup>a</sup> 11	<sup>a</sup> 4	<sup>a</sup> 9	<sup>a</sup> 6
Crescent City.....	Well	<sup>a</sup> 8	<sup>a</sup> 8	<sup>a</sup> 7	<sup>a</sup> 5	<sup>a</sup> 16	ND
Death Valley.....	Treated	42	<sup>a</sup> 10	<sup>a</sup> 2	<sup>a</sup> 4	<sup>a</sup> 8	<sup>a</sup> 6
Dos Palos.....	Treated	ND	ND	ND	<sup>a</sup> 10	ND	ND
El Centro.....	Treated	<sup>a</sup> 3	<sup>a</sup> 10	<sup>a</sup> 10	<sup>a</sup> 19	ND	<sup>a</sup> 24
Eureka.....	Raw	<sup>a</sup> 7	ND	ND	ND	<sup>a</sup> 21	ND
Los Angeles Laboratory.....	Treated	<sup>a</sup> 20	ND	<sup>a</sup> 6	<sup>a</sup> 3	ND	ND
Marin Municipal Water District.....	Raw	<sup>a</sup> 7	<sup>a</sup> 24	<sup>a</sup> 6	<sup>a</sup> 14	<sup>a</sup> 2	NS
Mariposa.....	Treated	ND	<sup>a</sup> 12	<sup>a</sup> 4	<sup>a</sup> 6	<sup>a</sup> 11	ND
Metropolitan Water District of Southern California:	Treated	<sup>a</sup> 6	<sup>a</sup> 9	<sup>a</sup> 5	NS	ND	<sup>a</sup> 12
Lake Havasu.....	Raw	40	<sup>a</sup> 3	NS	<sup>a</sup> 5	<sup>a</sup> 14	<sup>a</sup> 5
Weymouth Plant.....	Treated	<sup>a</sup> 14	<sup>a</sup> 23	<sup>a</sup> 16	<sup>a</sup> 24	<sup>a</sup> 6	<sup>a</sup> 15
Lake Millerton.....	Raw	ND	ND	<sup>a</sup> 2	<sup>a</sup> 11	<sup>a</sup> 25	<sup>a</sup> 4
Monterey.....	Treated	NS	ND	NS	NS	NS	ND
Napa.....	Treated	<sup>a</sup> 7	<sup>a</sup> 17	ND	ND	ND	<sup>a</sup> 7
Needles.....	Well	<sup>a</sup> 14	<sup>a</sup> 18	<sup>a</sup> 52	<sup>a</sup> 41	ND	ND
North Marin Water District.....	Treated	<sup>a</sup> 8	<sup>a</sup> 17	<sup>a</sup> 8	<sup>a</sup> 18	ND	<sup>a</sup> 19
.....	Raw	<sup>a</sup> 7	<sup>a</sup> 11	ND	ND	<sup>a</sup> 21	31
.....	Sludge <sup>b</sup>	<sup>a</sup> 2	<sup>a</sup> 1	<sup>a</sup> 17	171	ND	<sup>a</sup> 59
Oroville:							
California Water Service.....	Treated	<sup>a</sup> 16	<sup>a</sup> 18	NS	<sup>a</sup> 1	NS	NS
Wyandotte Irrigation District.....	Treated	<sup>a</sup> 17	ND	NS	NS	<sup>a</sup> 6	NS
Pleasanton.....	Well	ND	<sup>a</sup> 6	ND	ND	<sup>a</sup> 1	<sup>a</sup> 17
Redding.....	Treated	<sup>a</sup> 3	NS	<sup>a</sup> 9	ND	<sup>a</sup> 2	NS
Sacramento.....	Treated	NS	<sup>a</sup> 9	ND	<sup>a</sup> 3	<sup>a</sup> 3	<sup>a</sup> 9
Salinas.....	Well	NS	NS	NS	ND	NS	NS
San Diego.....	Raw	<sup>a</sup> 17	<sup>a</sup> 15	<sup>a</sup> 2	ND	<sup>a</sup> 22	NS
.....	Treated	<sup>a</sup> 9	ND	<sup>a</sup> 3	<sup>a</sup> 28	<sup>a</sup> 17	NS
San Francisco:							
Water Department.....	Raw	<sup>a</sup> 1	<sup>a</sup> 3	ND	<sup>a</sup> 22	ND	<sup>a</sup> 3
Alameda, East.....	Raw	ND	<sup>a</sup> 14	<sup>a</sup> 3	ND	ND	<sup>a</sup> 1
Brightside Weir.....	Raw	ND	<sup>a</sup> 17	<sup>a</sup> 1	<sup>a</sup> 7	<sup>a</sup> 1	ND
Calaveras Reservoir.....	Raw	ND	<sup>a</sup> 15	<sup>a</sup> 3	<sup>a</sup> 19	ND	<sup>a</sup> 3
Crystal Springs.....	Raw	ND	ND	ND	ND	<sup>a</sup> 2	<sup>a</sup> 5
Hetch Hetchy.....	Raw	<sup>a</sup> 3	<sup>a</sup> 2	ND	<sup>a</sup> 2	<sup>a</sup> 1	<sup>a</sup> 6
San Jose.....	Raw	ND	ND	ND	NS	ND	NS
Santa Barbara.....	Treated	<sup>a</sup> 12	<sup>a</sup> 3	ND	<sup>a</sup> 15	<sup>a</sup> 7	<sup>a</sup> 5
Santa Rosa.....	Raw	ND	ND	<sup>a</sup> 7	<sup>a</sup> 8	<sup>a</sup> 1	ND
Tahoe City.....	Raw	ND	<sup>a</sup> 4	<sup>a</sup> 2	ND	NS	NS
Ukiah.....	Well	ND	<sup>a</sup> 6	NS	NS	ND	NS
Vallejo:							
Fleming Hill.....	Raw	<sup>a</sup> 2	<sup>a</sup> 1	<sup>a</sup> 21	<sup>a</sup> 18	ND	<sup>a</sup> 5
Swansy Reservoir.....	Treated	ND	<sup>a</sup> 9	<sup>a</sup> 10	ND	ND	ND
Yosemite.....	Treated	ND	ND	<sup>a</sup> 23	<sup>a</sup> 3	<sup>a</sup> 9	<sup>a</sup> 6
.....	Treated	<sup>a</sup> 5	<sup>a</sup> 7	ND	<sup>a</sup> 12	ND	<sup>a</sup> 7
Maximum.....		42	24	52	171	32	59
Minimum.....		1	1	1	1	1	1

<sup>a</sup> When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best estimate but is not statistically significant.

<sup>b</sup> Sludge reported in pCi/g (dry weight).

NS, no sample collected.

ND, no detectable radioactivity.

## REFERENCE

(1) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analyses of environmental samples, R 59-6. Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (November 16, 1959).

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July-December 1965	November 1966
January-June 1966	June 1967

Table 2. Radionuclide concentrations in California surface water, 1966

Sampling station and date 1966	Concentration (pCi/liter)				
	Radium-226	Barium- lanthanum-140	Strontium-90	Strontium-89	Potassium-40
Antioch:					
January-June	0.05	NA	1	ND	* 1
Berkeley:					
January-June	0.01	* 34	1	ND	* 1
Dos Palos:					
March-August	0.14	* 11	ND	ND	* 2
El Centro:					
January-June	0.22	* 310	* 1	* 2	* 6
Lake Millerton:					
January-June	* 0.02	ND	* 1	NA	ND
Metropolitan Water District of Southern California:					
Weymouth Plant:					
January-June	NA	* 154	* 1	ND	* 4
Monterey:					
February-August	NA	ND	ND	ND	* 1
Napa:					
January-June	NA	ND	1	1	* 2
Needles:					
January-June	* 0.02	ND	ND	* 1	* 10
North Marin Water District:					
January-June	* 0.01	* 11	NA	NA	* 5
Oroville California Water Service:					
January-June	0.03	* 17	ND	ND	* 1 <sup>§</sup>
Wyandotte Irrigation District:					
January-June	ND	* 36	* 1	ND	ND
Redding:					
January-June	* 0.01	ND	ND	ND	* 2
Sacramento:					
April-September	NA	NA	NA	NA	* 2
San Diego:					
January-June	* 0.04	* 146	* 2	ND	* 4
San Jose:					
June-August 1965 <sup>b</sup>	NA	ND	ND	NA	* 1
January-June	* 0.03	ND	ND	* 1	* 2
Santa Barbara:					
January-June	0.08	* 15	* 1	ND	* 1
Santa Cruz:					
July-December 1965 <sup>b</sup>	0.04	ND	* 1	ND	* 2
January-June	* 0.02	* 33	* 1	ND	* 2
Santa Rosa:					
January-June	0.04	ND	ND	ND	* 2
Tahoe City:					
January-June	* 0.02	ND	NA	NA	* 1
Vallejo:					
May-June	0.01	* 4	* 1	ND	* 2
Yosemite:					
January-June	NA	3	* 1	ND	ND

Results for manganese-54, iodine-131 and cerium-141-144 for all stations were non-detectable during this period except for a value of \*1 pCi/liter for zirconium-niobium-95 and ruthenium-rhodium-106 at Needles and \*1 pCi/liter for cesium-137 at San Diego.

\* When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant.

<sup>b</sup> Data not previously reported.

NA, no analysis.

ND, no detectable activity.

### SECTION III. AIR AND DEPOSITION

#### Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the

Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
HASL Fallout Network	July-December 1966	September 1967
HASL 80th Meridian Network	Calendar Year 1965	January 1967
Plutonium in Airborne Particulates	January-March 1967	September 1967

## 1. Radiation Surveillance Network

October 1967

National Center for Radiological Health  
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 73 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity by the station operators. These estimates are made after the decay of radon and partial decay of thoron daughter products and prior to submission of the samples for laboratory analysis. When high air levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (1). A

detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*. The described procedures have been modified in that laboratory gross beta-particle counting and gamma-ray spectroscopy are no longer performed on air samples having a field estimate below 10 pCi/m<sup>3</sup>. Reporting field estimates only may cause an apparent increase in the published airborne radioactivity levels proportional to the amount of thoron daughter radioactivity present in the sample. In extreme cases, this increase may be as much as 2 orders of magnitude, but usually will be of the order of a factor of 2 or less. The maximum field estimates reported by RSN stations and attributable to thoron daughter radioactivity have ranged from 15 to 20 pCi/m<sup>3</sup> at 5 hours after collection.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates as measured by the field estimates, and deposition by precipitation during October 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.



Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, October 1967

Station location		Number of samples		Air surveillance, gross beta radioactivity (pCi/m <sup>3</sup> )			Last profile in RHD&R	Precipitation	
		Air	Pptn	Maximum	Minimum	Average <sup>a</sup>		Total depth (mm)	Total deposition (nCi/m <sup>2</sup> )
Ala:	Montgomery	31	3	10.53	0.42	3.72	Nov 67	72	<14
Alaska:	Adak	30		0.40	.36	0.36	June 67	e	
	Anchorage	21	3	.00	.00	.00	Dec 67	8	< 2
	Attu Island	6		.00	.00	.00	July 67	e	
	Fairbanks	b					Jan 68	e	
	Juneau	18	13	.36	.00	.02	Feb 68	222	<44
	Kodiak	10		1.40	.35	.56	May 67	e	
	Nome	31		1.16	.00	.44	Sept 67	e	
	Pt. Barrow	31		1.27	.59	.67	Aug 67	e	
	St. Paul Island	4		.90	.45	.57	Oct 67	e	
Ariz:	Phoenix	17		7.49	.20	2.74	Feb 68	e	
Ark:	Little Rock	15		2.76	.32	1.01	Dec 67	e	
Calif:	Berkeley	20	2	3.63	.00	.70	May 67	64	<13
	Los Angeles	21	1	2.34	.26	1.09	Sept 67	12	< 2
C. Z:	Ancon	17		1.88	.92	1.43	May 67	e	
Colo:	Denver	21		6.60	.67	2.87	May 67	e	
Conn:	Hartford	20	4	.97	.22	.33	Jan 68	64	<13
Del:	Dover	21		1.41	.19	.44	Nov 67	e	
D. C:	Washington	30	6	3.24	.27	1.03	Aug 67	49	<10
Fla:	Jacksonville	22	4	1.71	.35	.53	Dec 67	17	< 4
	Miami	14	11	.23	.06	.12	Jan 68	245	<49
Ga:	Atlanta	21	4	1.51	.35	.85	Oct 67	87	<18
Guam:	Agana	17		1.03	.00	.54	Nov 67	e	
Hawaii:	Honolulu	31		.86	.31	.44	July 67	e	
Idaho:	Boise	26	5	4.90	.63	2.34	July 67	26	< 5
Ill:	Springfield	19	2	3.18	.32	.83	Aug 67	18	< 4
Ind:	Indianapolis	21	8	2.07	.84	1.24	Oct 67	141	<28
Iowa:	Iowa City	17	6	2.33	.53	1.34	May 67	160	<32
Kans:	Topeka	19	8	3.10	.27	.98	Dec 67	105	<21
Ky:	Frankfort	20	5	2.86	.38	1.26	Aug 67	34	< 7
La:	New Orleans	22		.90	.07	.30	Aug 67	e	
Maine:	Augusta	21	8	1.29	.16	.48	Feb 68	88	<18
Md:	Baltimore	21	3	2.99	.26	1.00	Jan 68	25	< 5
	Rockville	3		3.24	.34	.96	July 67	e	
Mass:	Lawrence	21	7	3.15	.00	.75	Nov 67	42	< 9
	Winchester	21	7	1.79	.00	.63	June 67	35	< 7
Mich:	Lansing	22	11	3.46	.51	1.36	July 67	112	<22
Minn:	Minneapolis	19	4	.57	.19	.23	Nov 67	42	< 8
Miss:	Jackson	20	3	4.28	.19	1.17	Feb 68	49	<10
Mo:	Jefferson City	21	7	1.47	.18	.41	Oct 67	131	<26
Mont:	Helena	20	6	2.63	.24	.79	June 67	28	< 6
Nebr:	Lincoln	20	7	2.71	.52	1.24	Oct 67	19	< 4
Nev:	Las Vegas	26		2.32	.45	.90	Jan 68	e	
N. H:	Concord	21		2.50	.00	.92	Aug 67	e	
N. J:	Trenton	19	2	1.12	.16	.35	Feb 68	14	< 3
N. Mex:	Santa Fe	20	1	1.25	.16	.73	June 67	7	< 1
N. Y:	Albany	21	5	1.16	.17	.61	Oct 67	60	<12
	Buffalo	13		.36	.08	.19	May 67	e	
	New York City	21		.52	.15	.24	June 67	e	
N. C:	Gastonia	17		11.59	1.45	6.64	May 67	e	
N. Dak:	Bismarck	21	5	2.70	.34	1.19	Aug 67	57	<11
Ohio:	Cincinnati	20		4.95	.40	1.45	Nov 67	e	
	Columbus	21	3	3.55	.17	.89	Feb 68	33	< 7
	Painesville	18	12	1.54	.21	.54	Jan 68	70	<14
Okla:	Oklahoma City	19		.67	.00	.26	July 67	e	
	Ponca City	23	5	6.46	.08	.83	Jan 68	66	<13
Ore:	Portland	21	14	1.77	.09	.41	Oct 67	101	<20
Pa:	Harrisburg	20	1	4.02	.57	1.27	Oct 67	39	< 8
P. R:	San Juan	10	2	.00	.00	.00	Feb 68	63	<13
R. I:	Providence	21	5	1.92	.00	.36	July 67	90	<18
S. C:	Columbia	9	3	1.25	.27	.52	June 67	11	< 2
S. Dak:	Pierre	13		8.10	1.21	2.36	Feb 68	e	
Tenn:	Nashville	17	5	3.30	.30	1.40	July 67	38	< 8
Tex:	Austin	22		7.72	.12	2.26	Nov 67	e	
	El Paso	31	1	6.35	.41	3.63	Aug 67	2	< 1
Utah:	Salt Lake City	31	3	1.29	.24	.70	Sept 67	27	< 5
Vt:	Barre	21	9	2.27	.21	.57	Dec 67	104	<21
Va:	Richmond	17	5	1.52	.21	.78	Dec 67	37	< 8
Wash:	Seattle	b					Dec 67	e	
	Spokane	20	7	3.75	.53	1.50	Nov 67	21	< 4
W. Va:	Charleston	21	7	2.09	.24	.83	June 67	43	< 9
Wis:	Madison	21	9	1.67	.07	.53	Dec 67	133	<27
Wyo:	Cheyenne	22	1	4.91	.69	1.72	Jan 68	12	3
Network summary		1,419	253	11.59	0.00	1.01		62	<13

<sup>a</sup> The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.<sup>b</sup> Indicates no report received. (The data program does not distinguish between samples received without field estimate data and samples not received at all.)<sup>c</sup> Indicates no precipitation sample collected.

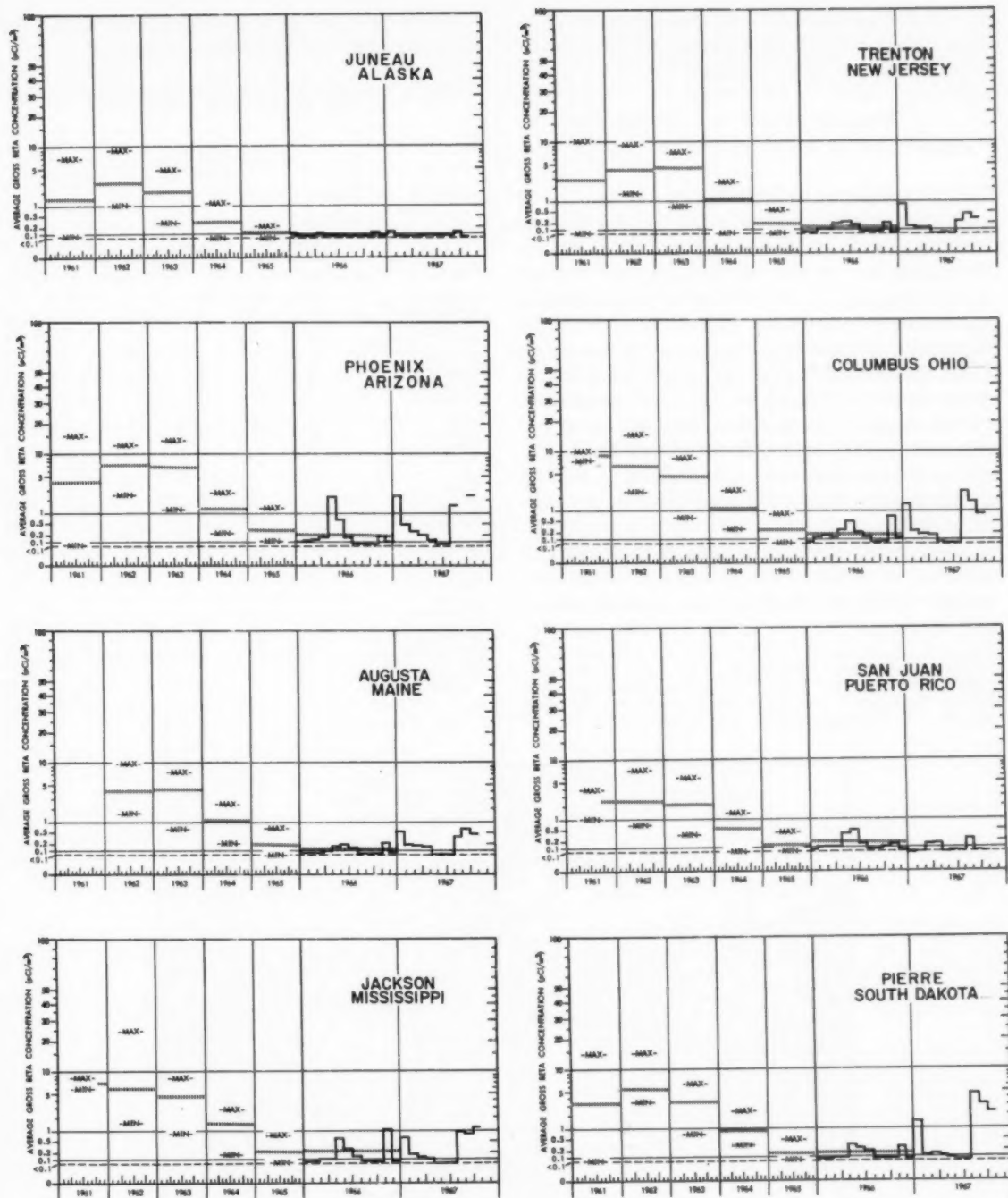


Figure 2. Monthly and yearly profiles of beta radioactivity in air—  
Radiation Surveillance Network, 1961–October 1967

## 2. Canadian Air and Precipitation Monitoring Program October 1967<sup>1</sup>

*Radiation Protection Division  
Department of National Health and Welfare*

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (2-6).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports*.

<sup>1</sup> Prepared from information and data in the November 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for October 1967 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, October 1967

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m <sup>3</sup> )			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m <sup>2</sup> )
Calgary.....	31	0.7	0.0	0.1	.4	20
Coral Harbour.....	29	.3	.0	.0	.1	3
Edmonton.....	31	.8	.0	.0	.4	11
Ft. Churchill.....	31	.4	.0	.0	.2	6
Ft. William.....	31	.0	.0	.0	1.0	21
Fredericton.....	21	.2	.0	.0	.6	12
Goose Bay.....	31	.0	.0	.0	.3	9
Halifax.....	31	.2	.0	.0	.5	3
Inuvik.....	31	.0	.0	.0	1.1	33
Montreal.....	31	.4	.0	.0	.7	10
Moosonee.....	31	1.5	.0	.1	.4	9
Ottawa.....	31	.0	.0	.0	.9	10
Quebec.....	31	.1	.0	.0	1.7	13
Regina.....	31	.1	.0	.0	.5	12
Resolute.....	31	.0	.0	.0	NS	NS
St. John's, Nfld.....	31	.4	.0	.0	1.2	10
Saskatoon.....	31	.3	.0	.0	.7	23
Sault Ste. Marie.....	31	.0	.0	.0	2.2	20
Toronto.....	31	.4	.0	.0	.8	14
Vancouver.....	31	.1	.0	.0	1.4	5
Whitehorse.....	31	.0	.0	.0	.1	9
Windsor.....	31	.4	.0	.0	1.1	11
Winnipeg.....	31	.6	.0	.1	1.0	22
Yellowknife.....	29	.0	.0	.0	.7	7
Network summary.....	740	1.5	0.0	0.0	0.8	13

NS, no sample.



Figure 3. Canadian air and precipitation sampling stations

### 3. Mexican Air Monitoring Program October 1967

#### *National Commission of Nuclear Energy*

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department

of the University of Mérida, the Institute de Zonas Désérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

#### *Sampling*

The sampling procedure involves drawing air through a high-efficiency 6-by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (7).

The maximum, minimum, and average beta-particle concentrations in surface air during October 1967 are presented in table 3.



Figure 4. Mexican air sampling stations

**Table 3. Mexican gross beta radioactivity of airborne particulates, October 1967**

Station	Number of samples	Gross beta radioactivity (pCi/m <sup>3</sup> )		
		Maximum	Minimum	Average
Acapulco.....	10	0.3	0.1	0.1
Chihuahua.....	1			
Ciudad Juárez.....	15	.7	.1	.1
Ensenada.....	12	.1	.1	.1
Guadalajara.....	NS			
Guaymas.....	NS			
La Paz.....	12	.1	.1	.1
Matamoros.....	NS			
Masatlán.....	7	.1	.1	.1
Mérida.....	3	.1	.1	.1
México, D. F.....	17	.1	.1	.1
Nuevo Laredo.....	NS			
San Luis Potosí.....	NS			
Tampico.....	12	.2	.1	.1
Torreón.....	15	.1	.1	.1
Veracruz.....	3	.1	.1	.1

NS, indicates no sample collected, station temporarily shut down.

#### 4. Pan American Air Sampling Program October 1967

*Pan American Health Organization and  
U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for

the Radiation Surveillance Network before July 31, 1967. The air sampling locations are shown in figure 5.

The October 1967 air monitoring results are given in table 4.

**Table 4. Gross beta radioactivity in surface air, PAHO October 1967**

Station location	Number of samples	Gross beta radioactivity (pCi/m <sup>3</sup> )		
		Maximum	Minimum	Average *
Argentina: Buenos Aires...	11	0.14	0.01	0.06
Bolivia: La Paz.....	19	.10	.01	.04
Chile: Santiago.....	29	.13	.02	.06
Colombia: Bogotá.....	17	.02	.00	.01
Ecuador: Guayaquil.....	27	.16	.00	.07
Jamaica: Kingston.....	20	.05	.01	.02
Peru: Lima.....	19	.27	.00	.13
Venezuela: Caracas.....	19	.06	.01	.02
West Indies: Trinidad.....	19	.07	.00	.02
Pan American summary...	180	0.27	0.00	0.04

\* The monthly average is calculated by weighting the specific activity of the individual air samples with the length of sampling period.



**Figure 5. Pan American Air Sampling Program stations**

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- (2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).
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## SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained

from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

### Iodine-131 in Bovine Thyroids, April–September 1967

*National Center for Radiological Health  
Public Health Service*

The National Center for Radiological Health established a bovine thyroid network in October 1964 (1). Specimens are collected by the Livestock Slaughter Inspection Division, U.S. Department of Agriculture, and analyzed by gamma-ray spectroscopy for iodine-131 content at the Northeastern Radiological Health Laboratory, Winchester, Mass.

The network consists of collection areas (counties shaded in figure 1) located so as to cover, as nearly as possible, areas near major

nuclear reactors, spent-fuel reprocessing plants and nuclear test sites. Details of sampling and analyses have been published earlier (1).

The results for April through September 1967 appear in table 1 and are listed chronologically within each state. The iodine-131 levels in thyroids analyzed were generally non-detectable although a small generalized rise to maximum levels of 20 to 25 pCi/g thyroid occurred in mid to late July.



Figure 1. Counties sampled in bovine thyroid network  
April–September 1967

Table 1. Iodine-131 in bovine thyroids, April-September 1967

State	Date(s) of slaughter	County	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
Arizona	* 4/3-9/29	Graham (2) * Maricopa (38)	43	b ND		
California	4/3 * 4/3-9/29	Merced Calaveras (2) * Fresno (7) Kern (1) Kings (1) Los Angeles (7) Madera (5) Merced (27) Monterey (12) Orange (7) Riverside (3) Sacramento (4)	2 188	10 b ND	ND	19
Georgia	* 4/4-7/5  7/11  * 7/17-9/26	Bartow (2) Bibb (1) Burke (6) Chatham (1) Clarke (10) Cobb (1) Columbia (9) Emanuel (2) Greene (3) Jefferson (4) Newton	70  3  54	b ND  6  b ND		
Idaho	* 4/15-7/7  7/14 7/21 * 7/25-9/29	Ada (18) Bonneville (5) Canyon (34) Cassia (7) Gem (5) Ada Canyon Ada (1) Adams (10) Canyon (15) Elmore (2)	77  5 2 37	b ND  18 9 b ND	9 8	22 9
Iowa	* 4/3-9/28	Lyon (12)	17	b ND		
Kansas	* 4/3-9/28	Douglas (7) Franklin (1) Johnson (1) Leavinworth (1) Linn (1)	19	b ND		
Louisiana	4/13 6/21 7/14 * 7/25-9/28	Natchitoches Natchitoches Red River Bossier (1) De Soto (1)	1 1 1 6	ND ND 9 b ND		
North Carolina	* 4/4-9/26	Cabarrus (8) Cleveland (8)	26	b ND		
New York	* 4/5-9/27	Chautauqua	180	ND		
Oklahoma	* 4/3-7/12  8/8 * 8/17-9/28	Bryan (2) Carter (4) Choctaw (1) Carter Bryan (2) Carter (2)	11  2 7	b ND  5 b ND	4	6
Oregon	* 4/15-7/7 8/7 * 8/15-9/29	Malheur (1) Harney Crook (4) Harney (9)	12 8 20	b ND 2 b ND	ND	7
South Carolina	* 4/4-7/19	Abbeville (2) * Aiken (3) Bamberg (5) Barnwell (7) Cherokee (2) Colleton (3) Greenwood (12) Laurens (1)	65	b ND		

See footnotes at end of table.

Table 1. Iodine-131 in bovine thyroids, April-September 1967—Continued

State	Date(s) of slaughter	County	Num- ber of samples	pCi iodine-131/g thyroid		
				Average or con- centra- tion	Mini- mum	Maxi- mum
South Carolina—Continued	7/25	Bamberg	1	8		
	* 7/25-9/26	Aiken (3) Greenwood (9) Bamberg (3) Lexington (5) Barnwell (3) Richland (7) Cherokee (4) Spartanburg (3) Colleton (2)	39	b ND		
South Dakota	* 4/3-6/30	Aurora (9) Lincoln (6) Brookings (6) Lyman (4) Brown (1) McCook (8) Clark (4) Minnehaha (13) Gregory (1) Roberts (1) Hamlin (6) Tripp (3) Hanson (1) Turner (3) Hutchinson (7) Yankton (1)	74	b ND		
	4/17	Minnehaha	2	5	ND	9
	7/11	Charles Mix	5	2	ND	8
	7/17	Faulk	4	8	6	10
	* 8/3-9/28	Charles Mix (3) McCook (4) Clark (1) Miner (8) Davison (10) Minnehaha (3) Grant (1) Roberts (4) Hanson (1) Yankton (2) Hutchinson (2)	39	b ND		
	* 4/4-6/28	Blount (17) Knox (18) Cumberland (2) Loudon (3) Grainger (2) Morgan (1) Green (1) Roane (1) Hamblen (2) Sevier (15) Jefferson (1)	63	b ND		
	7/5	Blount	2	6	5	6
		Lexington	2	ND		
	7/5	Loudon	1	3	7	9
	7/12	Sevier	2	11	8	13
Tennessee	7/19	Knox	4	11	8	16
		Blount	2	10	6	13
		Jefferson	1	7		
		Knox	2	15	6	24
		Sevier	1	4		
	7/26	Blount	2	2	2	2
		Knox	2	4	3	5
		Sevier	2	6	6	6
	8/2	Blount	1	6		
		Fentress	1	ND		
		Knox	4	4	3	5
	8/11	Blount	2	2	ND	4
		Sevier	3	2	ND	5
		Union	1	6		
	8/16	Blount	2	4	4	4
		Jefferson	1	8		
		Roane	2	15	5	24
		Sevier	1	3		
	* 8/22-9/26	Blount (13) Knox (8) Fentress (1) Loudon (1) Hawkins (1) Roane (1) Jefferson (2) Sevier (2)	29	b ND		
Texas	* 4/3-9/28	Cass (1) Hunt (2) Collin (2) Kaufman (1) Denton (10) Rains (4) Fannin (2)	22	b ND		
	* 4/15-7/27	Davis (10) Weber (6) Sanpete (5)	21	b ND		
Washington	* 4/15-9/29	Asotin (2) Walla Walla (52)	53	b ND		
Wisconsin	* 4/3-9/28	Dane (22) Rock (49) Green (9)	80	b ND		

\* Samples were not collected on all dates during this period, but the interval includes several sampling dates.

<sup>b</sup> The results for this period were, for the most part, not detectable. Some randomly scattered positive results were obtained; but these represented barely detectable amounts of iodine-131 in the bovine thyroid (2 to 5 pCi/g).

<sup>c</sup> Numbers in parentheses represent the number of samples collected from that county during the interval indicated. These may have been collected over several dates during the period or on only one date.

#### Recent coverage in Radiological Health Data and Reports:

Period  
January-June 1966  
July-December 1966  
January-March 1967

Issue  
January 1967  
April 1967  
August 1967

#### REFERENCE

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## Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational

Safety in directives published in the AEC Manual.<sup>1</sup>

Summaries of the environmental radioactivity data follow for the Hanford Atomic Products Operation, Pinellas Peninsula Plant, and the Savannah River Plant.

<sup>1</sup> Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

### 1. Hanford Atomic Products Operation Calendar Year 1966<sup>2</sup>

*Battelle Memorial Institute  
Richland, Washington*

Surveillance of the Hanford environs during 1966 showed that both the concentrations of radioactive materials in the vicinity and the environmental radiation doses were well within appropriate limits.

Results obtained from the Hanford environmental surveillance program for 1966 indicated that most of the environmental radiation dose for the majority of persons living in the Hanford environs was due to natural sources and world-wide fallout rather than to Hanford operations. The major source of low-level wastes released to the environment from Hanford plants was reactor cooling water, which was discharged to the Columbia River.

Two events occurred during 1966 which significantly influenced radiation levels in the Hanford environs. The first of these was an abnormal release of radioiodines from a produc-

tion reactor to the Columbia River on February 11, 1966. The net effect of this release was to increase the thyroid dose to the typical Richland child from 6 percent of the limit (1965) to 9 percent of the limit (1966).

The second event resulted in a significant reduction of radiation levels in the Hanford environs during a 2-month period. A strike was called against Hanford contractors on July 8, 1966. Within a few days, all reactors were shut down and remained out of operation until late August. The overall effect of the extended reactor shutdown was to reduce the estimated annual doses to the GI tract, whole body, and bone, by as much as 2 percent of the appropriate limits from the 1965 values.

The highly unlikely but plausible combination of living habits that would result in an individual's receiving the largest radiation dose from Hanford-effluent radionuclides is postulated as:

1. Consumption of 200 meals per year of fish caught down river from the reactors,
2. spending 500 hours per year on the riverbank to catch the above quantity of fish,
3. consumption of meat, milk, fruit, and vegetables from irrigated farms in the Riverview district, and
4. consumption of drinking water from the Pasco system.

A person with such habits is called the

<sup>2</sup> Summarized from Pacific Northwest Laboratory, Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966, BNWL-439 (June 1967).

"maximum individual." During 1966, the "maximum individual" could have conceivably ingested enough radioactive materials of Hanford origin (mostly phosphorus-32) to provide an intake of 10 percent of the MPRI (Maximum Permissible Rate of Intake) specified by the AEC-ICRP (International Commission on Radiological Protection) for individuals in the general population (with bone as the critical organ). This same intake would have resulted in annual doses for 1966 that were 5 and 7 percent of the appropriate AEC-FRC (Federal Radiation Council) guidance for the GI tract and whole body, respectively.

The typical Richland resident received most of his radiation dose from natural background

and world-wide fallout. The radiation dose from Hanford sources received by this population group originates, for the most part, from drinking water obtained from the Columbia River. Normally, the radiation dose received by the GI tract is the largest percentage of appropriate limits for the mixture of radionuclides present in drinking water. During 1966, however, the unusual release of radioiodines mentioned earlier resulted in an estimated maximum thyroid dose of 40 mrem. The dose to the 2 g thyroid of a typical Richland child as a result of the radioiodine release was 20 mrem. Including the latter increment, the thyroid dose to a typical Richland child for 1966 was only 9 percent of the limit.

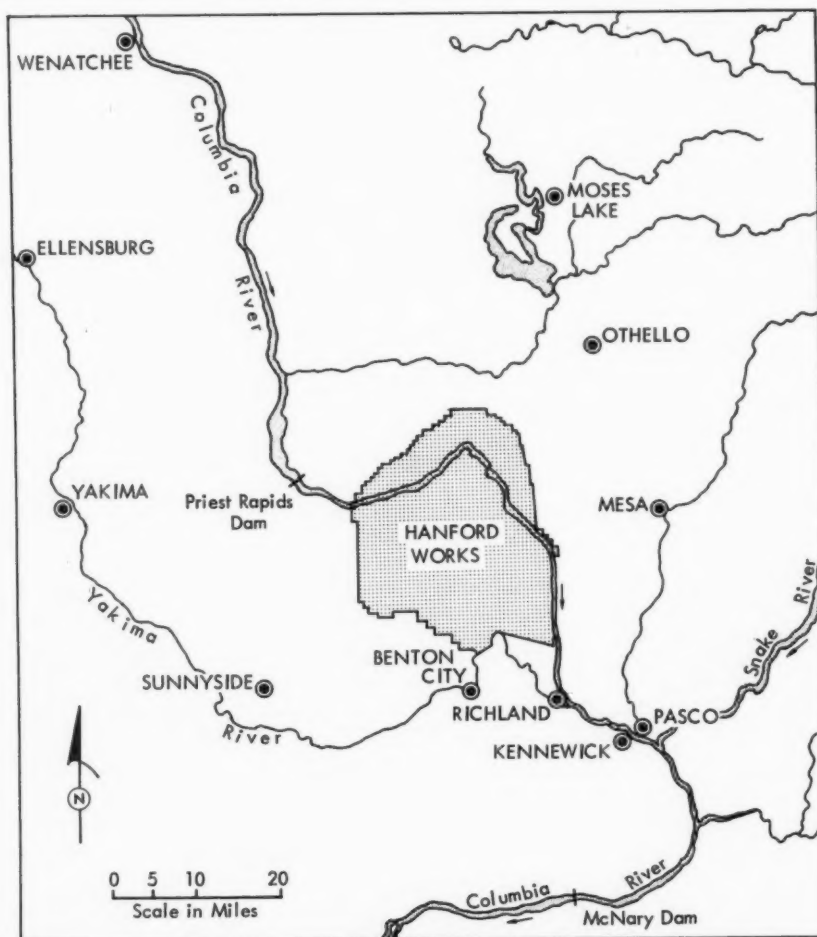


Figure 1. Hanford project environs

Except for the unusual release of radioiodines to the river during February, iodine-131 concentrations in the Hanford environs were at very low levels during 1966. Brief increases in iodine-131 concentrations in the environment occurred following the foreign nuclear weapons test of May 9 and October 27, 1966, but concentrations soon returned to the low levels experienced during most of 1966.

The Hanford plant<sup>3</sup> is located in a semiarid region of southeastern Washington State, where the average annual rainfall is about 16 cm (6 in.). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the project have gradually been put under irrigation during the past few years. The plant site (figure 1) covers an area of about 1,300 km<sup>2</sup> (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Near the plant production sites, the prevailing winds are from the northwest with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated areas of primary interest are the tri-cities (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello; and these together with the surrounding agricultural area, bring the total population near the plant to about 80,000 people.

During the course of operation, various radioactive wastes are generated by the several plant facilities. High-level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage is not feasible, are made to the ground. Practices governing radioactive waste disposal at the Hanford Plant are described in the Hearings on Industrial Radioactive Waste Disposal held by the Joint Committee on Atomic Energy, U.S. Congress in 1959 (1).

<sup>3</sup> Operated during 1966 for the Atomic Energy Commission by the Batelle-Memorial Institute, Douglas-United Nuclear, Inc., the General Electric Company, Isochem, Inc., and ITT/Federal Support-Services, Inc.

It is the purpose of this report to present an evaluation of the combined off-project effects of the radioactive-waste-disposal practices of all Hanford contractors. Radiation protection practices, including the effects of radioactive waste disposal, are governed by AEC Manual Chapters 0524 and RL 0524 (2). The section to which this evaluation is addressed stipulates that radioactivity in effluents released to uncontrolled areas shall not result in a radiation dose to individuals exceeding 0.5 rem/yr to the whole body or gonads or 1.5 rem/yr to the thyroid or GI tract.

The significance of bone seekers such as phosphorus-32 and strontium-90 requires special consideration and treatment because the rate of intake of phosphorus-32 has not been specifically studied by the Federal Radiation Council (FRC) (3) in relation to a dose-equivalent for the bone or bone marrow.

Where the FRC does not provide direct guidance, they suggest that ICRP-NCRP (National Council on Radiation Protection and Measurement) dosimetry methods be used (4,5). The ICRP values are used as a reference base, because the ICRP-NCRP recommendations imply a more conservative rate of intake for phosphorus-32. Rather than introduce additional confusion associated with dose-equivalents for bone derived by different techniques, the data for bone seekers have been expressed in terms of a maximum permissible rate of intake (MPRI).

The MPRI is taken as the maximum permissible concentration (MPC) in water for a given radionuclide, as recommended by the ICRP for persons in the neighborhood of controlled areas, multiplied by the rate of water intake as defined for the standard man. This amounts to one-tenth of the MPC for continuous occupational exposure multiplied by intake rates of 2.2 liters/day or 800 liters/yr (for annual estimates). In the case of phosphorus-32 the MPRI is 16  $\mu$ Ci/yr.

The radiological units used throughout most of this report are mrems (dose-equivalent). For the nuclides of interest at Hanford, and the organs for which radiation doses (in mrad) and dose-equivalents (mrems) are calculated, the number of rads equal the number of rems.

Included in this report are two types of

measurements which are not necessarily relevant to dose evaluations. These are the concentrations of radionuclides in the Columbia River and concentration of iodine-131 in cattle thyroids which serve as trend indicators and as support for data used in dose calculations.

All of Hanford's production reactors use Columbia River water for cooling. The N-reactor uses recirculating demineralized water as a primary coolant. All waste water containing significant amounts of radioactive materials is filtered through the ground before it reaches the river. The amount of radioactive material reaching the river from N-reactor is a negligibly small fraction of that released from the older reactors.

At the older reactors, some elements present in the cooling water are transformed into radionuclides during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river.

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some fraction of most radionuclides is removed from the river water by sedimentation and by uptake by aquatic organisms. Also present in the river are radionuclides contributed by fallout from nuclear weapons testing.

Samples of river water were collected above the production areas at Priest Rapids Dam and below the areas at the Richland water plant intake, McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was installed and provided a more representative sample than the periodic grab samples obtained in the past. This cumulative sampling technique, however, makes it impractical to calculate the amounts of very short-lived nuclides; these must still be measured from grab samples. Within a few days after the July-August reactor shut down began, concentrations of reactor-effluent radionuclides in the Columbia River dropped to very low levels (in most cases, below the analytical limit). However, concentrations of zinc-65 did not drop as much as would be expected from known releases of this radionuclide to the river. It was evident that a significant amount of zinc-65 was retained in the river bed and was re-

cycled to the water through continued scouring and leaching of the sediments.

The annual average concentrations of radionuclides measured routinely at Richland and Bonneville Dam are shown in table 1.

Table 1. Annual average radioactivity in Columbia River water, 1966

Radioactivity	Activity concentration (pCi/liter)	
	Richland	Bonneville Dam
RE+Y <sup>a</sup> .....	270	( <sup>b</sup> )
Sodium-24.....	2,600	( <sup>b</sup> )
Phosphorus-32.....	140	23
Chromium-51.....	3,600	1,300
Copper-64.....	1,400	( <sup>b</sup> )
Zinc-65.....	200	43
Arsenic-76.....	420	( <sup>b</sup> )
Strontium-90.....	1	( <sup>b</sup> )
Iodine-131.....	18	3
Neptunium-239.....	770	( <sup>b</sup> )

<sup>a</sup> Rare earths plus yttrium.

<sup>b</sup> Insufficient sampling data to provide a meaningful annual average.

Measurements on traverses across the river at Richland indicate a slightly nonuniform distribution of the longer-lived radioisotopes at this cross-section. Entries of the Yakima River some 16 km (10 miles) above Pasco and of the Snake River some 48 km (30 miles) above McNary Dam slightly influence the distribution of radionuclides below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries. Bonneville Dam is approximately 490 km (240 miles) below the Hanford reactors and represents the farthest downstream location where river water is routinely sampled for Hanford's environmental surveillance program.

The seasonal variation in flow rate of the Columbia River markedly affects the quantity of water available for dilution of reactor effluent released to the river. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another. The annual average transport rate of selected radionuclides past the Bonneville Dam is given in table 2.

An estimate of the inventory of these radionuclides which exist in the ocean may be calculated by assuming an equilibrium between the rate of addition through the river and the rate

of decay in the ocean. A constant rate of entry into the ocean equivalent to that indicated by the 1966 Bonneville Dam measurements would imply an inventory of about 190 curies of phosphorus-32, 17,000 curies of chromium-51, and 7,400 curies of zinc-65.

**Table 2. Annual average transport rate past Bonneville Dam of selected radionuclides, 1963-1966**

Radionuclide	Transport rate (Ci/day)			
	1963 *	1964	1965	1966
Phosphorus-32	12	12	11	9
Chromium-51	860	860	800	430
Zinc-65	28	44	49	21

\* Rate of transport at Vancouver, Wash.

### Radionuclides in drinking water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of drinking water supply. Pasco and Kennewick, a few miles farther downstream, also use the Columbia River as a source of drinking water. Continuous potable water samples were collected at the Richland water plant, and periodic samples were collected at Pasco and Kennewick. All of these samples were analyzed for the important individual radionuclides. The results of analyses of drinking water from these three cities are summarized in table 3.

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than the values shown in table 3 because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand.

The calculated annual average dose to whole body, the GI tract and thyroid, and the percent MPRI for bone from sustained consumption of drinking water throughout the year at the three cities are presented in table 4.

The GI tract dose of Richland and Pasco residents was significantly lower in 1966 (about 10 percent and 30 percent, respectively) than in 1965 (6,7).

This is primarily attributed to the retirement

of the three Hanford reactors and the extended shut down of all reactors during the summer of 1966.

The thyroid dose, however, was somewhat higher during 1966 than during 1965 (10), because of the unusual release of radioiodines to the river on February 11, 1966. The estimated thyroid dose (as a direct result of the release) received by a typical Richland child (2 g thyroid) drinking 0.4 liter of water per day was 20 mrem. The annual thyroid dose (including the above) to the same child from drinking water for 1966 was estimated to be 35 mrem. The maximum dose to a 2 g thyroid was estimated from a water intake rate of 0.8 liter per day. Such an intake rate would have resulted in thyroid doses from drinking water of 40 mrem during February 1966, and 70 mrem for the entire year. Corresponding thyroid doses for 1965 were 20 mrem for the typical Richland child and 40 mrem for the maximum child.

**Table 3. Annual average concentration of radioactivity measured in drinking water, 1966**

Radioactivity	Radioactivity concentration (pCi/liter)		
	Richland	Pasco	Kennewick
Total beta	5.6	1.7	0.32
RE+Y *	77	28	(b)
Sodium-24	1,700	540	64
Phosphorus-32	92	36	11
Chromium-51	4,200	3,100	1,300
Copper-64	430	68	39
Zinc-65	68	70	<20
Arsenic-76	200	46	12
Strontium-90	<1	<1	(b)
Iodine-131	14	9	12
Neptunium-239	560	370	57

\* Rare earths plus yttrium.

<sup>b</sup> Insufficient data to provide a meaningful annual average.

**Table 4. Calculated annual dose for selected organs from routine ingestion of drinking water, 1966<sup>a</sup>**

Location	Whole body (mrem)	GI tract (mrem)	Bone (percent of MPRI)	Thyroid (small child 0.4 liter/day) (mrem)
Richland	1.9	31	0.8	35
Pasco	<1	9	0.1	22
Kennewick	<1	1	<0.1	30

<sup>a</sup> Here and elsewhere in this report where a dose (mrem) from an ingested nuclide is expressed, the determination is made from parameters used by the ICRP to translate dose rates into maximum permissible concentrations for drinking water. In most cases, the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart and Minake (9).

Note: The "standard man" average intake rate of 1.2 liter/day was used in this calculation (4).

### *Radionuclides in fish and waterfowl*

The Columbia River is popular for sports fishing above and below the Hanford plant, and the fish that feed downstream from the reactors acquire some radionuclides from the reactor effluent. Whitefish are the sports fish that usually contain the greatest concentration of radioactive materials. Further, they can be caught during winter months when other sports fish are difficult to sample. For these reasons, whitefish are sampled most intensively to follow trends.

Concentrations of phosphorus-32 in whitefish during 1966 tended to follow seasonal trends observed in past years; however, phosphorus-32 concentrations in the fall months were at much lower levels than in previous years (6,7), primarily as a result of the extended reactor shut down during the summer. Concentrations of zinc-65 in whitefish were affected little by the extended reactor shut down, probably owing to recycling of this radionuclide from the river bottom during the shut down period. The average concentrations of phosphorus-32 and zinc-65 in whitefish sampled down stream from the reactors during 1966 were 110 pCi/g and 23 pCi/g, as compared with 200 pCi/g phosphorus-32 and 27 pCi/g zinc-65 during 1965.

The quantities and kinds of fish caught by local fishermen have been estimated previously from surveys carried out by personnel of the State of Washington, Department of Game. Additional dietary data collected during 1966 did not change these estimates. Those individuals who probably ingest the largest amounts of phosphorus-32 are fishermen who claim to eat bass, crappie, and perch, as often as three to five times a week. This large number of fish meals indicates an annual intake of about 40 kg (about 90 pounds) of fish. On the basis of the 40 kg of fish consumption claimed by the "maximum individual" (200 fish meals/year), the intake of phosphorus-32 during 1966 could have been approximately 1.0  $\mu$ Ci, or approximately 6.2 percent of the MPRI for bone as the critical organ.

Many persons have been counted in the Hanford whole-body counter, including some avid fishermen. Amounts of zinc-65 detected in these people were much less than expected on the

basis of their stated consumption of fish. These results supported the findings of the past years which suggested that fishermen tend to overestimate their fish consumption. Therefore, the actual ingestion rates of both phosphorus-32 and zinc-65 are undoubtedly substantially lower than currently postulated from the fishermen's estimates.

Migratory waterfowl, such as ducks and geese, which have utilized the Hanford section of the Columbia River and the swamps and ponds within the project boundaries may contain phosphorus-32, zinc-65, and small amounts of other radionuclides. Some of these waterfowl remain in this general area throughout the year. One hundred twenty-four of the water fowl samples collected during 1966 had concentrations of phosphorus-32 less than 50 pCi/g of flesh (wet weight), 51 samples were above 50 pCi/g but less than 500 pCi/g, and the remaining 10 samples were over 500 pCi/g. The maximum concentration of phosphorus-32 was 2,900 pCi/g. However, as a potential source of this radionuclide to people, the waterfowl are of much less significance than the fish because they cannot be harvested in such large numbers by individuals and because of "dilution" by large flights of migrating birds that move through the region at the time of the year when hunting is allowed.

### *Radionuclides in marine organisms*

Zinc-65 and phosphorus-32 are the only radionuclides in the reactor effluent that are found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of zinc-65 than other common seafood organisms. The extended reactor shut down during the summer of 1966 had very little effect on concentrations of phosphorus-32 and zinc-65 in oysters. In the case of phosphorus-32, a normal seasonal minimum occurs in the late summer; and in the case of zinc-65 recycling from the river bottom held zinc-65 concentrations near their normally expected levels.

Annual average concentrations of zinc-65 have decreased over the past 3 years while phosphorus-32 concentrations have remained

at about the same level during that time (6,7). The average concentrations in samples taken throughout 1966 were 28 pCi/g, zinc-65 and 2.9 pCi/g, phosphorus-32.

Consumption of oysters containing these concentrations at the rate of 50 g/day<sup>4</sup> would result in an annual dose of about 6 mrem to the GI tract and 4 mrem to the whole body. These intakes represent 0.4 percent of the MPRI for bone as the critical organ.

#### *Radionuclides in the atmosphere*

At Hanford, gaseous waste from the chemical separations facilities is released to the atmosphere through 70 meters high (230 feet) stacks after most of the radioactive materials have been removed by filtration and scrubbing. These radioactive materials are primarily associated with process vessel off-gases. Ventilation air from laboratory and reactor building contains comparatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine-131 were made routinely at numerous locations within the Hanford reservation and around the plant perimeter. The results of iodine-131 measurements for the past few years are summarized in table 5.

Table 5. Annual average iodine-131 concentrations in the atmosphere, 1963-1966

Location	Distance from separation stacks (miles)	Iodine-131 (pCi/m <sup>3</sup> )			
		1963	1964	1965	1966
Promer Barricade <sup>a</sup> .....	14	(b)	0.02	0.03	0.02
Benton City.....	20	0.03	.06	.03	.01
Richland.....	23	.02	.02	.02	.01
Pasco.....	32	.02	.01	.03	.01

<sup>a</sup> Installed during October 1963.

<sup>b</sup> Insufficient sampling data to provide a meaningful annual average.

The four locations listed in table 5 lie within a 45° sector southeast to south of the separations center. Such concentrations sustained in inspired air imply an annual dose to the thyroid of the "standard man" of less than 1 mrem.

Air filter sampling is maintained at several locations within the Hanford reservation and around the plant perimeter. Air filter results are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination.

<sup>4</sup> Expected to be used as a reference consumption rate in future national shellfish quality standards.

Sudden changes in concentration are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

#### *Radionuclides in milk and produce*

The radioactivity found in locally grown agricultural produce can be influenced by deposition of airborne radionuclides or by irrigation with river water containing reactor effluent radionuclides. The chemical separations facilities are generally the principal local source of airborne radionuclides. The closest farming area to the separations facilities is about 21 km (13 miles) away.

Most irrigated farms near the Hanford plant use water drawn from the Yakima River, or from the Columbia River above the project. There are, however, two small areas which regularly take water from the Columbia River downstream from the reactors for irrigation. They are the Ringold farms and the Riverview district west of Pasco, located respectively 24 and 48 km downstream from the reactors.

The principal products from the larger farm plots are hay, fruit, beef, and dairy products. This area is centered 48 km (30 miles) southeast of the chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 20 miles (32 km) directly south of the separations facilities.

A comprehensive milk surveillance program maintained during 1966 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. The concentrations of radionuclides found in milk sold by commercial outlets were similar to that reported by the U.S. Public Health Service and the Washington State Department of Health. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus-32 and zinc-65 as well as fission products of fallout origin.

Generally, the average concentration of iodine-131 in both local and commercial milk was at or below the analytical limit of 3 pCi/liter. Brief increases in iodine-131 concentrations were noted in June, following the foreign atmospheric nuclear weapons test on May 9; in July and October, following small, transient in-

creases in the release rate of iodine-131 from a chemical separations facility; and in November, following the foreign atmospheric nuclear tests on October 27. The maximum concentration of iodine-131 observed in milk was 15 pCi/liter on June 2, 1966.

Dairy farms in the Ringold and Riverview area that utilize the Columbia River for irrigation of pasture land and hay fields produce milk containing both phosphorus-32 and zinc-65. The extended reactor shut down during July and August had very little effect on the concentrations of these two nuclides in milk because of other variables, such as irrigation and feeding practices. During 1966, the average concentration of phosphorus-32 in milk from Ringold and Riverview farms was 480 pCi/liter and the average concentration of zinc-65 was 370 pCi/liter. Commercial milk distributed in the tri-cities usually does not contain phosphorus-32 and zinc-65 because it is obtained principally from areas not irrigated with Columbia River water.

Adult residents consuming milk (1 liter/day) obtained from the Ringold-Riverview area would receive an annual dose from phosphorus-32 and zinc-65 amounting to about 5 mrem to the GI tract and 2 mrem to the whole body. The intake of phosphorus-32 and zinc-65 would be equal to about 1.2 percent of the MPRI for bone. The intake of iodine-131 would have resulted in a dose of about 2 mrem to the thyroid.

Miscellaneous fresh farm produce was sampled periodically for radioanalysis during the 1966 growing season from local farms and commercial outlets. Results of these measurements were similar to those of previous years (6,7) and indicated that only small quantities of radionuclides are present in locally grown produce.

The concentrations of iodine-131 found in samples of fresh vegetables collected from local farms and markets during the period of May through September 1966, were less than or approximately equal to the analytical limit of 0.05 pCi/g. There was no significant difference noted in concentrations found in local farm produce and in produce purchased from commercial outlets. If these fresh vegetables had been consumed at the rate of 100 g/day throughout the year, the average annual intake from

this source would have been about 730 pCi for iodine-131. Such an intake would imply an annual dose of about 1 mrem to the thyroid of a typical adult Richland resident.

#### *Concentrations of iodine-131 in cattle thyroids*

Thyroids of cattle are collected periodically from slaughter houses in Moses Lake, Yakima, Walla Walla, Wenatchee, and Pasco, and are sent to Hanford for radioanalysis. The average concentrations measured in beef thyroids were generally at or below the analytical limit of 5 pCi/g for iodine-131 during most of 1966, except for a brief increase in June following the May 9, 1966, foreign atmospheric nuclear weapons test, and in November following the foreign atmospheric nuclear weapons tests in October. The maximum concentration of iodine-131 in bovine thyroids was 150 pCi/g from samples collected in November at Pasco and Walla Walla.

#### *External radiation*

Ionization chambers are stationed on the Hanford reservation and in Richland to estimate the gamma radiation exposure from external sources. Measurements in air 1 meter above ground during 1966 averaged about 0.36 mR/day or 130 mR/yr at Hanford and about 0.28 mR/day or 100 mR/yr at Richland, somewhat lower than measured during the past 3 years (6,7). Essentially all of this exposure is from natural background and worldwide fallout from nuclear testing.

Direct radiation measurements are also made in the Columbia River at several locations with pocket-type ionization chambers submerged 0.6 to 1.5 meters (2 to 5 feet) below the surface of the water. Exposure rates are higher in the river than overground because of the presence of gamma-ray emitters (especially sodium-24) in reactor effluent. In the vicinity of Richland, the average exposure rate in the water during the months of April through October was about 2 mR/day. A person swimming or boating in the river for a total of 240 hours during the year could have received a whole-body exposure of 20 mR.

An estimate of the external radiation exposure received by people that fish from the shore in the vicinity of the Hanford project is compli-

cated by the daily fluctuation in the level of the river but the exposure rate at the river's edge during 1966 was lowest during the freshet in late June and highest during low river flow rates in the fall months. Recent measurements of the gamma-ray spectrum indicate that zinc-65 accumulated by algae growth on the substrate at the river's edge is responsible for a major portion of a fisherman's radiation exposure. Assuming that an avid fisherman spent as many as 500 hours on the river bank in the vicinity of Richland during 1966, his external exposure could have been about 13 mR.

#### *Radioactive wastes released to ground*

Liquid wastes from the chemical separations areas are routed to various facilities dependent upon their burden of radionuclides. High-level wastes (normally containing concentrations greater than 100  $\mu\text{Ci/ml}$ ) are stored in underground concrete tanks lined with steel. Intermediate level wastes (ordinarily containing concentrations in the range of  $5 \times 10^{-5}$   $\mu\text{Ci/ml}$  to 100  $\mu\text{Ci/ml}$ ) are sent to underground "cribs" from which they percolate into the soil. The areas selected for intermediate waste disposal and high level waste storage have soil with good ion exchange capacity and ground water depths of 50 to 100 meters (165 to 330 feet). Low-level wastes (usually containing less than  $10^{-5}$   $\mu\text{Ci/ml}$ ) are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of the relatively large volumes of water. Wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks and to measure radionuclides that have reached the ground water. Virtually all of the radionuclides present in the ground water have been introduced with liquids sent to the cribs. The bulk of this radioactive material is ruthenium-rhodium-106. A substantial amount of tritium has also been sent to the ground with the intermediate level liquid wastes from the separations plants.

In all probability, some tritium and ruthenium-rhodium-106 originating at the chemical processing areas is now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the river

water and any exposure from them is therefore negligible.

#### *Fallout from nuclear weapons testing*

In addition to the radiation dose received by residents of the Hanford environs from Hanford-originated radionuclides and from natural background radiation, a dose increment due to fallout nuclides is also received. Locally this increment is below the national average because of the low rainfall in this region (6.3 inches/year). Measurements of fallout, like measurements of natural background radiation, are necessary to place the radiation dose resulting from Hanford operations into proper perspective. The fallout nuclides of interest during 1966 were tritium, strontium-90, iodine-131, and cesium-137. Although a small transient increase in iodine-131 concentrations was observed in June and November (following the foreign atmospheric nuclear weapons tests) the resulting thyroid dose was negligible.

Tritium (another fallout radionuclide), although occasionally detectable in Columbia River water, was at such low levels (2 nCi/liter) that routine consumption of water obtained from the Columbia River implied an annual dose to the whole body of the "maximum" individual of less than 1 mrem.

Concentrations of strontium-90 measured in milk produced locally are similar to concentrations found in commercial milk produced in areas that are remote from the Hanford plant. Strontium-90 found in milk from local farms averaged about 5 pCi/liter. The concentration of cesium-137 in milk analyzed at Hanford was generally near the analytical limit of 30 pCi/liter. Worldwide fallout is the principal source of strontium-90 and cesium-137 in milk.

About 10 percent of the total intake of strontium-90 by local residents during 1966 came from drinking water obtained from the Columbia River. As in the case of milk, this strontium-90 was of fallout origin.

Based on the same dietary information used in other sections of this report, the total intake of strontium-90 during 1966 was about 0.006  $\mu\text{Ci}$  for the "maximum" individual and 0.005  $\mu\text{Ci}$  for the "typical" Richland resident. The total intake of cesium-137 during 1966 was

about 0.02  $\mu\text{Ci}$  for both the "maximum" individual and the "typical" Richland resident. The estimated annual dose from fallout radionuclides present in the Hanford environs is given in table 6.

Table 6. Annual radiation dose from fallout radionuclides, 1966

Radionuclide	Organ	Radiation dose (mrem)	
		Maximum individual	Average Richland resident
Tritium-----	Whole body	<1	<1
Strontium-90	GI tract-----	<1	<1
	Whole body-----	5	5
	Bone-----	(2 percent MPRI)	(5 percent MPRI)
Cesium-137---	GI tract-----	<1	<1
	Whole body-----	<1	<1
	Bone-----	(0.1 percent MPRI)	(0.1 percent MPRI)

For calculating a dose to the thyroid gland, the most appropriate sample of the exposed population would appear to be small children living in Richland who drank water from the municipal system (0.4 g/day), milk (0.6 liter/day) obtained from the local stores, and fresh vegetables (25 g/day) obtained from local markets. The total intake of iodine-131 during the year from these sources would be about 2,600 pCi, or an average of about 7 pCi/day. This intake is within FRC Range I and indicates a radiation dose of 44 mrem (9 percent of the limit) for 1966 (figure 3).

The estimated whole body dose (figure 3) of the average Richland resident from radionuclides of Hanford origin was 4 mrem. Whole body doses from natural background (excluded from the FRC Guide) and fallout sources in this region are estimated at about 100 mrem/year, and 5 mrem/year, respectively.

Table 7 provides a summary of radiation doses estimated for individuals and population groups residing in uncontrolled areas in the Hanford environs.

#### Radiation exposure summary

It is not possible to determine the precise radiation dose received by every individual because of variations in the kind and quantity of food consumed, variations in sources of food supply, and many variations in personal living

Table 7. Summary of radiation doses in uncontrolled areas of the Hanford environs, 1966<sup>a</sup>

Organ	"Maximum" individual			Average Richland resident		
	Annual dose (mrem)	Limit (mrem)	Percent of limit	Annual dose (mrem)	Limit (mrem)	Percent of limit
GI tract-----	70	1,500	5	33	500	7
Thyroid (infant) <sup>b</sup> ---	86	1,500	6	44	500	9
Whole body-----	33	500	7	4	170	2
Bone-----	( <sup>c</sup> )	( <sup>d</sup> )	( <sup>e</sup> )	( <sup>d</sup> )	( <sup>e</sup> )	( <sup>f</sup> )

<sup>a</sup> Represents individuals or population groups residing in uncontrolled areas near the Hanford plant.

<sup>b</sup> As a result of the radioiodine release during February, the maximum thyroid dose during 1966 was not received by a Riverview (Paaco) infant as in past years. A Richland child with similar dietary habits received an annual thyroid dose of 86 mrem, while the Riverview child received a thyroid dose of 61 mrem for 1966.

<sup>c</sup> Not calculated.

<sup>d</sup> AEC-ICRP MPRI for "maximum" individual—16  $\mu\text{Ci}$  <sup>90</sup>P/yr and 800  $\mu\text{Ci}$  <sup>90</sup>Zn/yr.

<sup>e</sup> AEC-ICRP MPRI for "typical" Richland resident—5.3  $\mu\text{Ci}$  <sup>90</sup>P/yr and 270  $\mu\text{Ci}$  <sup>90</sup>Zn/yr.

<sup>f</sup> Value represents percent of maximum permissible rate of intake specified by the International Commission on Radiological Protection for individuals in the general population.

habits. These inherent variations among individuals require a somewhat subjective approach when estimating the probable radiation exposure in relation to various established limits. The FRC has provided two sets of guides against which doses from environmental sources may be judged; that is, one for the individuals that receive the greatest dose, and the other for the average dose received by the general population (taken as one-third of that set for individuals). For the Hanford environs, doses from the various sources described in the preceding sections have been compiled in two ways to allow comparisons with guides for both the individual and the general population. In one case, a hypothetical but plausible individual has been assigned dietary and other habits that would result in what would seem to be the greatest rational dose. For the general population a dose has been estimated for what is called the "typical" Richland resident<sup>5</sup>.

Some residents may receive a larger dose than calculated for the "typical" Richland resident but it is improbable that any would receive as much as that calculated for the "maximum" individual. Included in this intermediate group

<sup>5</sup> The infeasibility of obtaining completely realistic dietary data for the typical resident leads to the assumptions which tend to slightly overestimate his dose. For example, it is assumed that no radioactive decay takes place during the transport of drinking water to the user and that no radioactivity is lost from food during preparation.

are families that subsist largely on foodstuffs produced on farms irrigated with water taken from the Columbia River downstream from the reactors.

### The "maximum" individual

Attempts have been continued to identify the individuals living in the Hanford environs that receive the greatest radiation dose. Experience accumulated from the environmental surveillance program indicates such individuals are undoubtedly persons that frequently eat fish caught locally in the Columbia River, and foodstuffs grown on farms irrigated with Columbia River water. Additional data collected during 1966 continued to support the assumption that fish, consisting mainly of crappie, perch, and bass, caught near Burbank (figure 2) are the most important source of radionuclides for the "maximum" individual. On the basis of an assumed consumption of 200 fish meals/year and radiochemical analyses of such fish, the intakes of phosphorus-32 and zinc-65 for the "maximum" individual during 1966 would have amounted to 1.0 and 0.5  $\mu\text{Ci}$ , respectively. Whether this amount of fish was actually eaten

by the individual was not confirmed. However, other persons reporting an unusually high consumption of local fish were counted in the whole body counter and were found to have far less zinc-65 deposited than predicted on the basis of their estimates of the quantities of fish eaten. As a basis for calculating the intake of radionuclides from fish, we have continued to use the maximum reported consumption of 200 fish meals per year.

The consumption rates of other foods for the hypothetical "maximum" individual are based on the maximum intakes described in various dietary surveys. It is assumed that each day this individual consumes 2 liters of water from the Pasco system, 1 liter of milk, 230 grams of beef, 20 grams of chicken, 80 grams of eggs, 200 grams of fresh leafy vegetables (in season), and 1,400 grams of all other vegetables and fruits, all produced on river irrigated farms in the Riverview District. The composite doses from these sources are illustrated in figure 2.

In past year, the maximum thyroid dose has been attributed to a child living in the Riverview farm district (Pasco). On the basis of a daily intake of 1 liter of farm milk, 50 grams of fresh-leafy farm vegetables, and 0.8 liter of water from the Pasco system, the thyroid dose received by a Riverview child during 1966 was 61 mrem (4 percent of the limit). However, a Richland child with similar dietary habits received a higher thyroid dose during 1966 than the Riverview child as a result of the radioiodine released during February. On the basis of a daily intake of 1 liter of commercial milk, 50 grams of fresh leafy commercial vegetables, and 0.8 liter of water from the Richland system, the thyroid dose received by the "maximum" child during 1966 was 86 mrem, or 6 percent of the FRC radiation protection guide for individuals.

### The "typical" Richland resident

The vast majority of people who live in Richland obtain their food from local commercial stores (rather than directly from farms) and consume little or no fish caught from the Columbia River. The principal sources of radionuclides ingested by these people are from worldwide fallout and from drinking water obtained from the Columbia River.

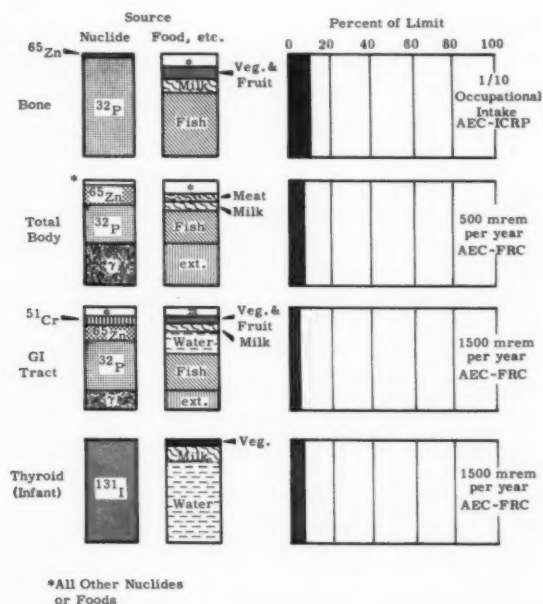


Figure 2. Estimated dose to "maximum" individual, 1966

The contribution from Hanford-created radionuclides in drinking water is substantially different for the three cities as discussed previously in the section on radionuclides in drinking water. The GI tract dose in Richland was greater than in the cities farther down river because the short-lived nuclides are in greater abundance. As shown in figure 3, the estimated dose to typical Richland residents for 1966 was about 33 mrem, or 7 percent of the maximum permissible dose. Ninety-three percent of the GI tract dose was contributed by drinking water.

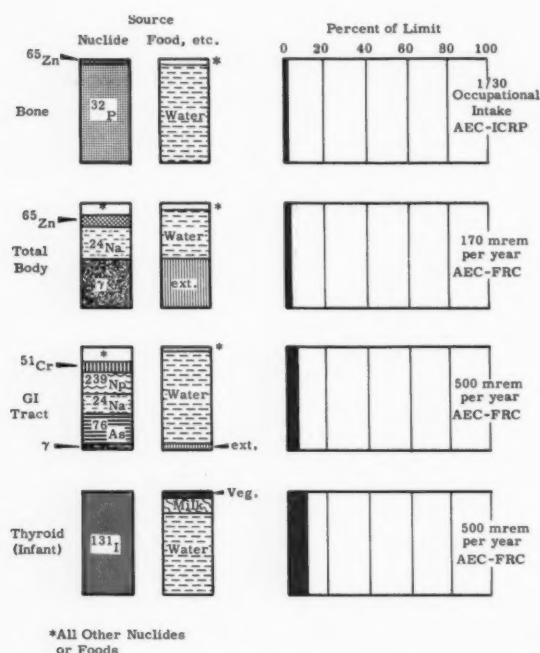


Figure 3. Estimated dose to "typical" Richland resident 1966

### Conclusions

During 1966, the environmental surveillance program of the Hanford environs again showed that the amounts of radioactive materials present were well within nationally accepted limits at all times.

A release of radioiodines to the river from a production reactor on February 11, 1966, war-

ranted special assessment of the radiation dose to persons in the Hanford environs. The effect of the release was to increase the thyroid dose received by the "typical" Richland child from 6 percent of the limit (1965) to 9 percent of the limit for 1966, and to have the maximum annual thyroid dose (86 mrem) occur in Richland rather than in the Riverview district.

The effect of the 2-month reactor shutdown period following the July 8 strike against Hanford contractors was to contribute to a reduction in the GI tract and whole body doses by about 1 percent of the applicable limits and then to help reduce the percent MPRI (bone) for the "maximum" individual from 12 percent (1965) to slightly less than 10 percent during 1966. The retirement of three Hanford reactors during 1964-1965 also contributed to the reduction in environmental radiation doses during 1966.

### Recent coverage in Radiological Health Data and Reports:

Period	Issue
Calendar year 1964	February 1966
Calendar year 1965	February 1967

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## 2. Pinellas Peninsula Plant January-June 1967<sup>a</sup>

*General Electric Company  
St. Petersburg, Florida*

Pinellas Peninsula Plant, shown in figure 4 is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous nonoccupational exposure established by AEC and documented in the "AEC Manual."

### *Sewer effluent monitoring*

A combined sewer effluent sample is obtained daily near the perimeter of the plant's property. During the sampling period 25 of 246 samples analyzed showed detectable concentrations of tritium ( $90 \times 10^4$  pCi/liter)<sup>1</sup>. The maximum concentration,  $1.2 \times 10^6$  pCi/liter, which was detected on May 12, 1967, amounted to 39 percent of the continuous nonoccupational exposure guide. Calculations based on radioactivity releases from the process waste system, and the plant's water discharges, indicate that the average tritium concentration in the combined sewer effluent for the first half of 1967

was less than 7.3 percent of the AEC Radiation Protection Standard for continuous nonoccupational exposure.

### *Air monitoring*

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the one sample collected during the sampling period revealed no detectable amounts of tritium gas ( $9.6 \times 10^6$  pCi/m<sup>3</sup>) or tritium oxide ( $5.0 \times 10^3$  pCi/m<sup>3</sup>).

### *Surface water sampling*

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium oxide ( $9.0 \times 10^4$  pCi/liter) in the 39 surface water samples analyzed during the sampling period.

### *Milk sampling results*

Eighteen samples of raw milk were collected from local dairy farms and analyzed by the Florida State Board of Health during the first half of 1967. No detectable concentrations ( $9.0 \times 10^4$  pCi/liter) of tritium were evident.

### *Recent coverage in Radiological Health Data and Reports:*

Period	Issue
January-June 1966	February 1967
July-December 1966	July 1967

<sup>a</sup> Summarized from "Environmental Monitoring, January 1 through June 30, 1967," General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Fla.

<sup>1</sup> Expressions in parenthesis indicate limits of detectability in the respective environmental samples.

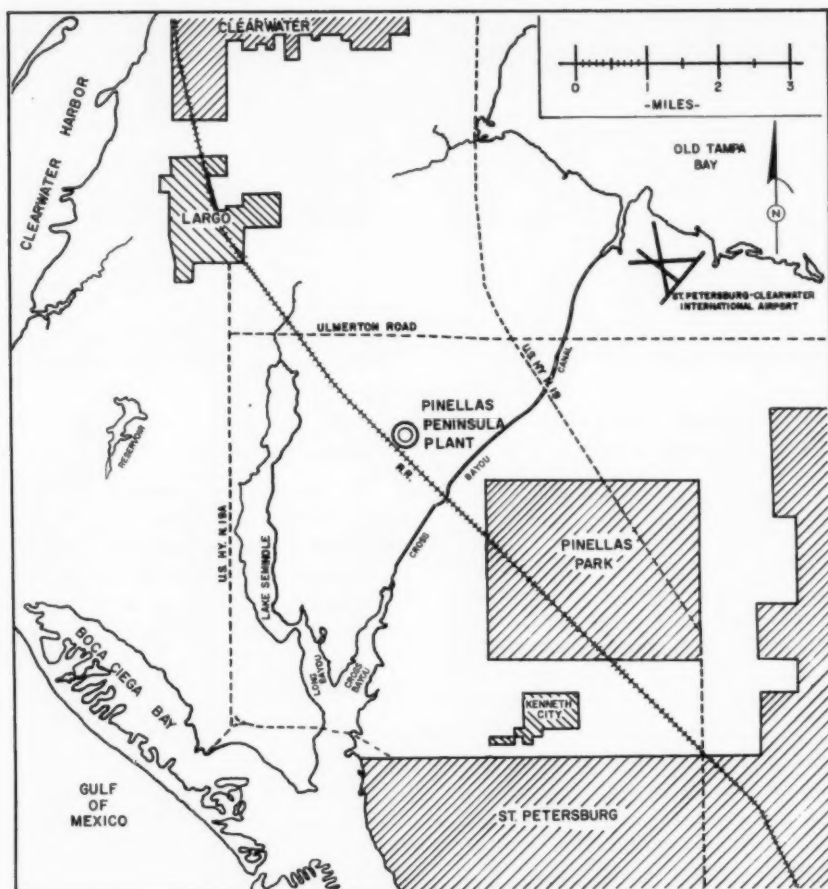


Figure 4. Location of Pinellas Peninsula Plant

### 3. Savannah River Plant January-June 1967<sup>\*</sup>

*E. I. du Pont de Nemours  
Aiken, South Carolina*

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, four reactors, two fuel separation areas, and a heavy water produc-

tion plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low-level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

The DuPont environmental monitoring group has maintained a continuous monitoring program since 1951 (before plant startup) to

<sup>\*</sup> Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, January-June 1967," (DPST-67-30-2).

determine the concentrations of radioactive materials in a 1,200-square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the maximum permissible concentrations (MPC) recommended by the International Commission on Radiological Protection (ICRP), or the daily intake guides recommended by the Federal Radiation Council (FRC).

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity cannot be readily distinguished from weapons tests fallout, and both are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

#### Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by biweekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about 25-mile radius from the center of the plant (figure 5). Deposition rates of radioactive material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S. C., are so distant from SRP that the effect of SRP operations is negligible; they are reference points for determining background radioactivity levels (figure 6). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between weapons test fallout and SRP releases.



Figure 5. Environmental sampling locations, Savannah River Plant

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separations areas, was obscured by fallout from nuclear weapons tests. The influence of the weapons tests which resumed in September 1961 is shown in figure 7. The rises in early 1964, 1965, and 1966 were the result of the anticipated spring increases in the mixing of stratospheric debris into the troposphere. The concentrations of radionuclides in air during June 1967, as in October 1966 were the lowest ever measured in this area.

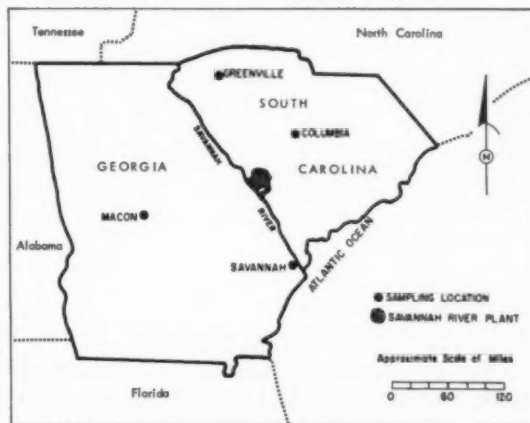


Figure 6. Distant air monitoring stations, Savannah River Plant

Radioactivity in air, determined from filter analyses, is shown in table 9. The January-June 1967 concentrations of filterable beta radioactivity ( $0.15 \text{ pCi/m}^3$ ) and alpha radioactivity ( $0.0007 \text{ pCi/m}^3$ ) in air were 0.2 and 1.8 percent of the respective MPC's. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile stations, did not exceed 1.1 percent of the MPC. Iodine-131 concentrations in routine air samples were less than 0.02

$\text{pCi/m}^3$ , the lower detection limit, throughout the period.

Deposition of weapons tests fallout during the first half of 1967 totaled  $23 \text{ nCi/m}^2$  at the plant perimeter locations and  $20 \text{ nCi/m}^2$  at 25-mile radius locations; comparable values for the last half of 1966 were 27 and  $21 \text{ nCi/m}^2$ . Deposition at each sampling location is presented in table 8.

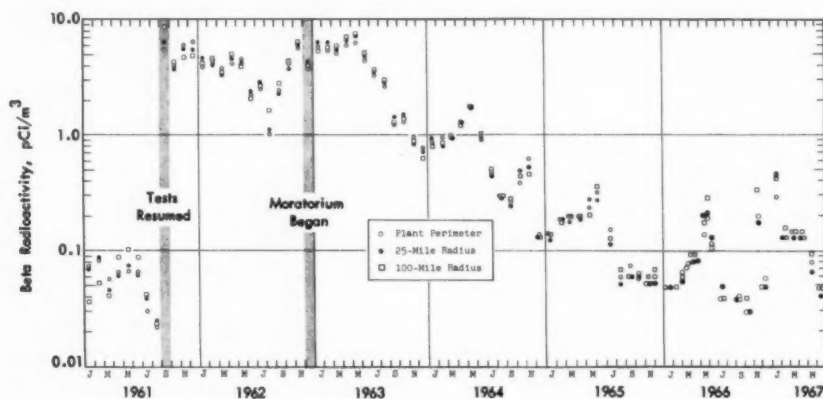


Figure 7. Influence of weapons tests

Table 8. Total fallout deposited, Savannah River Plant, January-June 1967

Radionuclide	Deposition ( $\text{nCi/m}^2$ )																
	Plant perimeter locations						25-mile radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allen- dale	Barn- well	Bush Field	Lang- ley	Sar- dis	Way- ne- boro	Will- iston	High- way 301	Aver- age
Alpha <sup>a</sup> .....	3.28	2.35	3.78	2.74	3.63	3.17	0.62	2.20	1.74	1.89	2.43	3.17	1.39	2.05	2.01	2.08	1.97
Strontium-89.....	1.51	0.96	1.93	1.00	1.78	1.43	0.77	0.66	1.62	0.96	0.62	0.77	0.97	1.93	1.35	1.43	1.12
Strontium-90.....	0.54	0.46	0.42	0.58	0.62	0.54	0.42	0.66	0.54	0.42	0.69	0.58	0.46	0.54	0.50	0.42	0.54
Iodine-131.....	1.81	1.70	0.54	1.70	2.05	1.54	2.39	0.62	1.47	1.27	3.17	2.01	1.70	2.39	0.39	1.85	1.74
Cesium-137.....	1.08	0.85	0.93	0.96	1.12	1.00	0.69	1.00	0.85	0.95	0.93	1.00	0.77	0.77	0.69	0.85	0.85
Cesium-141, -144.....	2.20	1.20	1.74	1.16	1.35	1.54	1.00	1.24	1.89	1.08	2.01	1.51	1.70	1.70	0.85	1.54	1.47
Ruthenium-103, -106.....	3.59	2.78	3.13	4.05	3.28	3.36	2.62	1.81	2.74	1.97	5.29	3.47	1.74	3.01	2.43	2.47	2.74
Barium-lanthanum-140.....	2.78	3.40	3.28	6.60	7.03	4.63	9.50	2.32	2.86	1.39	5.21	4.01	2.47	10.38	3.74	4.59	4.63
Zirconium-niobium-95.....	1.70	0.81	1.16	1.00	1.16	1.16	0.84	0.93	1.47	1.16	1.78	1.35	1.47	1.08	0.85	1.51	1.24
Beryllium-7.....	8.22	8.03	5.91	5.17	10.58	7.57	4.90	4.48	6.21	3.71	6.64	11.19	5.67	5.37	5.79	7.41	6.14

<sup>a</sup> Multiply by  $10^{-3}$ .

#### Algae and fish in Savannah River

Fish, predominantly bream, and indigenous algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected weekly, upstream from, adjacent to and downstream

from the Savannah River Plant. Determination of radionuclides in algae is important because algae concentrate certain radionuclides and also because of the role of algae in the food chain of aquatic organisms. Beta-particle con-

Table 9. Radioactivity in air, Savannah River Plant, January-June 1967

Filter analysis	Average concentration (pCi/m <sup>3</sup> )																
	Plant perimeter locations						25-mile radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Alen- dale	Barn- well	Bush Field	Lang- ley	Sar- dis	Waynes- boro	Will- iston	High- way 301	Average
Alpha particle emitters <sup>a</sup> (multiply by 10 <sup>-3</sup> )																	
Maximum-----	1.2	1.4	1.5	0.9	1.0	-----	1.2	2.8	1.1	1.2	2.4	1.4	0.9	1.0	1.2	1.1	-----
Minimum-----	0.3	0.4	ND	.3	0.3	-----	ND	ND	ND	ND	0.3	0.3	ND	ND	0.3	ND	-----
Average-----	.7	.7	0.7	.6	.6	0.6	0.6	0.6	0.6	0.6	.8	.9	.4	.6	.6	0.6	0.6
Nonvolatile beta- particle emitters <sup>b</sup>																	
Maximum-----	.53	.59	.41	.44	.61	-----	.84	.32	.68	.81	.42	.66	.41	1.39	.93	.31	-----
Minimum-----	.02	.02	.03	.02	.02	-----	.02	.02	.01	.02	.02	.03	.02	.02	.02	.02	-----
Average-----	.14	1.3	.11	0.13	.14	0.13	.18	.12	.16	.17	.13	.14	.15	.21	.17	.12	0.1
Specific radionuclides (averages)	Composite sample						Composite sample										
	Strontium-90, -90-----						0.008										
	Cesium-137-----						.006										
	Cerium-141, -144-----						.020										
	Ruthenium-103, -106-----						.029										
	Zirconium- niobium-95-----						.006										

<sup>a</sup> Sensitivity of analysis— $3.0 \times 10^{-4}$  pCi/m<sup>3</sup>; ICRP Maximum Permissible Concentration: 0.04 pCi/m<sup>3</sup>.

<sup>b</sup> Sensitivity of analysis—0.006 pCi/m<sup>3</sup>; ICRP Maximum Permissible Concentration: 100 pCi/m<sup>3</sup>.  
ND, less than sensitivity of analysis.

centrations in algae and fish adjacent to and downstream from SRP indicate some minor contribution by SRP. Although measurably higher than similar material collected at the control station 3 miles upstream from SRP, the slight increase is of no biological significance.

Specific radionuclide analyses were made on algae and fish collected from the Savannah River. Radiocesium and radiostrontium were found consistently in river algae; whereas cerium-141-144, chromium-51, zirconium-niobium-95, manganese-54, zinc-65, and cobalt-60 were detected less frequently. Also, radiostrontium (maximum, 20 pCi/g, wet weight) was detected in bone tissue of river fish, and radiocesium (maximum, 78 pCi/g, wet weight) was detected in the flesh tissue. Radiozinc and phosphorus-32 were detected less frequently in these tissues. The maximum concentrations of phosphorus-32 detected in bone and flesh tissues of river fish were 719 pCi/g and 5 pCi/g, respectively.

#### Water monitoring

The plant site is drained by five streams which flow several miles through the reservation before reaching the river (figure 8). In

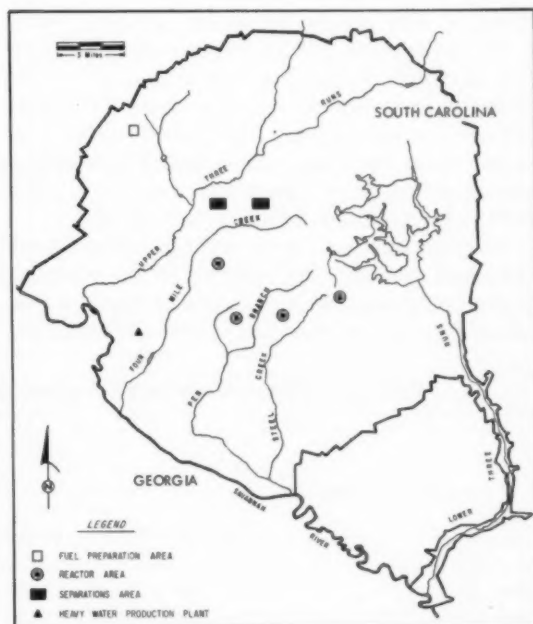


Figure 8. SRP production areas and effluent streams

January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish drinking water, partially supplied from the Savannah River, to most of

Beaufort County, South Carolina. Water is supplied through a new canal from the river at a location about 90 miles below the SRP. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand.

Communities near SRP get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed in April. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.4 pCi/liter) and beta radioactivity (6 pCi/liter) were essentially the same as those observed before plant startup.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 8. Average concentrations of specific radionuclides found in river water during January-June 1967 are in table 11.

Cesium-137, tritium, and trace amounts of chromium-51, and strontium-90, released mainly from reactor areas, were the radionuclides of SRP origin detectable in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river water upstream from SRP. The tritium concentrations in finished water collected from the Beaufort-Jasper Water Plant averaged 4,800 pCi/liter (0.5 percent of the MPC) during the 6-month report period.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy water moderator in the reactors. Chromium-51, the

second most abundant radionuclide released to the river, is produced by neutron irradiation of stable chromium (a component of the stainless steel used in reactor parts). Tritium and chromium-51 are among the least dangerous of all radionuclides because neither concentrates in body tissues. The tritium and chromium-51 concentrations in river water averaged 1.2 and 0.001 percent of the MPC, respectively.

### Milk

Milk was sampled at three dairies within a 25-mile radius of SRP, as shown in figure 9. Samples which were collected biweekly, were analyzed for tritium, radiocesiums, and radioiodine. Strontium-90 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during January-June 1967 are in table 10.

Average concentrations of three radionuclides in milk (30 pCi/liter for cesium-137, 20 pCi/liter for strontium-90, and less than 7 pCi/liter for iodine-131) were consistent with values reported by the U.S. Public Health Service for most sections of the United States during the first half of 1967. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level was less than the sensitivity of the analysis which allows detection of concentrations of 3,000 pCi/liter (1 percent of the MPC for water).

Table 10. Radioactivity in milk from local dairies, Savannah River Plant, January-June 1967

Location of local dairies	Concentration (pCi/liter)										
	Tritium <sup>a</sup>			Strontium-90 <sup>b</sup>		Iodine-131 <sup>c</sup>			Cesium-137 <sup>d</sup>		
	Maximum	Minimum	Average	March	June	Maximum	Minimum	Average	Maximum	Minimum	Average
Aiken.....	6,000	<3,000	<3,000	21	18	240	<5	8	<30	<30	<30
North Augusta.....	7,000	<3,000	<3,000	20	NS	23	<5	<5	<30	<30	<30
Waynesboro.....	<3,000	<3,000	<3,000	NS	NS	57	<5	<5	<30	<30	<30
Major distributors <sup>e</sup> .....	5,000	<3,000	<3,000	19	24	330	<5	10	<30	<30	<30

<sup>a</sup> Sensitivity of analysis—3,000 pCi/liter.

<sup>b</sup> Sensitivity of analysis—1.0 pCi/liter.

<sup>c</sup> Sensitivity of analysis—5.0 pCi/liter.

<sup>d</sup> Sensitivity of analysis—30 pCi/liter.

<sup>e</sup> Milk produced in local dairies, but sold by major distributors.

NS, no sample collected.

## Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or absorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at nine other locations along a 25-mile radius route. (These are not designated on figure 5). Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis. Radionuclides in grass samples were from weapons test fallout. Alpha-particle emitters averaged 0.2 pCi/g at the plant perimeter and 25-miles radius locations as compared to 0.1 pCi/g during the last half of 1966; gamma-ray emitters averaged 32 and 37 pCi/g, respectively, as compared to 24 and 21 pCi/g for the last half of 1966.

## Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The January-June 1967 data (shown in table 12), are character-

Table 11. Average concentration of radionuclides in Savannah River water, January-June 1967

Radionuclide	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (3 miles upstream from plant)	Highway 301 (10 miles downstream from plant)	Percent MPC at Highway 301
Tritium	600	1,200	12,200	1.2
Ruthenium-103, -106	3.2	<3.2	<3.2	<0.10
Cerium-141, -144	2.5	<2.5	<2.5	<.08
Cesium-134, -137	0.6	<0.6	<2.5	0.4
Neptunium-239	2.2	<2.2	<2.2	<.01
Barium-lanthanum-140	1.6	<1.6	<1.6	<.02
Zirconium-niobium-95	.5	<.5	<0.5	<.002
Chromium-51	4.3	<4.3	5.2	.001
Strontium-90	.3	<.3	<.3	-----
Iodine-131	.5	<.5	<.5	-----
Strontium-90	.01	.8	1.3	-----
Cobalt-60	1.4	<1.4	<1.4	<.007
Zinc-65	1.1	<1.1	<1.1	<.004
Manganese-54	.4	<.4	<.4	<.001

istic of measurements observed at individual stations for the past several years.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-June 1966	February 1967
July-December 1966	September 1967

Table 12. Environmental gamma radiation, Savannah River Plant, January-June 1967

	Exposure (mR/day)														
	Plant perimeter locations						25-mile radius locations								
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Alledale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston
Maximum	0.33	0.29	0.42	0.27	0.30	-----	0.41	0.24	0.32	0.31	0.33	0.38	0.29	0.40	0.44
Minimum	.22	.17	.21	.16	.12	-----	.17	.15	.18	.17	.19	.19	.17	.16	.18
Average	.27	.25	.30	.23	.22	0.25	.25	.17	.23	.24	.25	.23	.24	.24	.30
															0.26
															.15
															.22
															0.24

## Reported Nuclear Detonations, January 1967

The U.S. Atomic Energy Commission announced four underground nuclear detonations during January 1968. On January 18, 1968 an underground nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted at the AEC Nevada Test Site. Some radioactivity was accidentally released as a result of this test. While most of this radioactivity was deposited within the test site, some low level radioactivity was detected on the ground southwest of the site. The highest levels of radioactivity offsite were determined to be 0.7 milliroentgen per hour at Danby Ranch, which is less than 10 miles from the test site. This level of radioactivity presents no health hazard.

On January 19, 1968, an underground nuclear test of low-intermediate yield (20 to 200 kilotons TNT equivalent) was conducted at the Nevada Test Site.

On January 19, 1968, a nuclear test of intermediate yield (200 kilotons to 1 megaton TNT equivalent) was conducted underground by the AEC in the upper Hot Creek Valley of central Nevada.

The purpose of the test was to provide earth shock measurements to help determine whether the area is suitable for nuclear testing at higher yields than are possible at the Commission's permanent Nevada Test Site in the southwestern part of the State.

A decision on such use of the area must await analysis of data from this test and from other studies of the area.

On January 26, 1968, an underground nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted at the Nevada Test Site. This nuclear excavation experiment was part of the Plowshare Program to develop peaceful uses of nuclear explosives. The detonation was carried out at a buried depth of 170 feet and had a yield of about 2.5 kilotons. A crater about 125 feet deep and 400 feet in diameter was produced. The purpose of this experiment (called "Project Cabriolet") is to develop nuclear excavation technology and to provide information about cratering effects in hard dry rock.

### Errata

Errata to article "Measurements of X-Ray Exposure from a Home Color Television Receiver" by Rechen, Lee, Schneider and Briscoe in *Radiological Health Data and Reports*, Vol. 8, December 1967, pp. 687-697.

Page i, Contents, change spelling of author's name from "Brisco" to "Briscoe"

Page 687, 1st column, 2nd paragraph, 3rd line—change "loaded" to "loaned"

Page 687, 2nd column, last paragraph—change sentence to read as follows: "X-ray exposure rates from the viewing faceplates of the cathode ray tubes under all typical operating conditions were well below NCRP recommendations."

Page 688, 1st column, 3rd paragraph, 5th line—change word from "on" to "or"

Page 690, table 1—change "C<sub>a</sub>" in the heading of the 2nd column to "V<sub>a</sub>"

Page 691, table 2, footnote "c", 2nd line—change word "roster" to "raster"

Page 692, 1st column, last paragraph, 4th line—change both references from table "4" to table "3"

Page 692, 2nd column, change first equation as follows:

$$R_{30} = R_{117} \times \left( \frac{117}{30} \right)^2$$

Page 692, last paragraph, 1st line—change the reference from table "3" to table "4"

Page 693, 1st column, 2nd paragraph—change the reference in line 3 from footnote "a" to footnote "b"

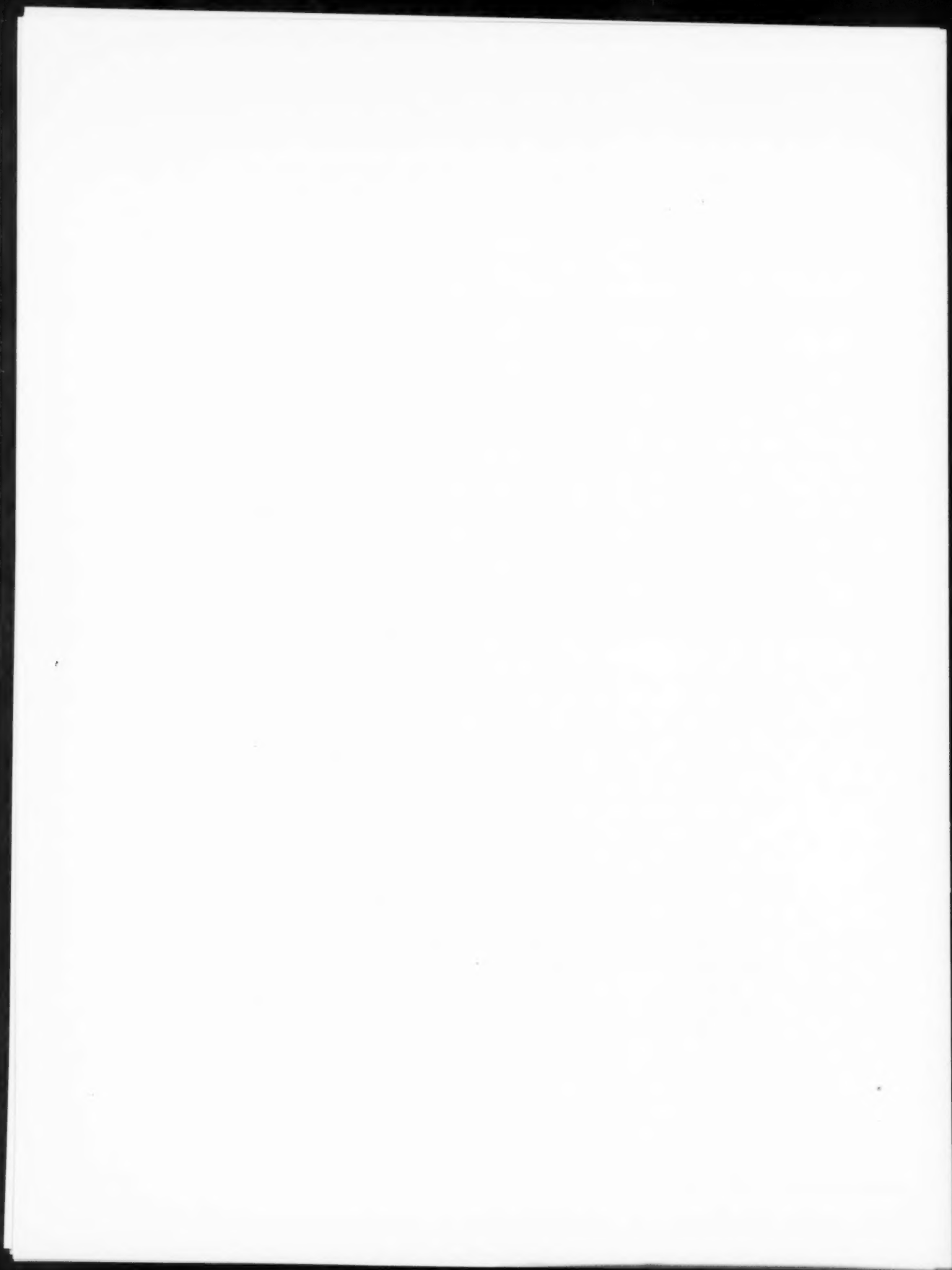
Page 695, 2nd column, 2nd paragraph—change the sentence starting on line 13 to read as follows: "The beam intensity decreases faster than the "inverse square" of distance because of air absorption and scatter."

Page 696, 1st column, 1st paragraph—change first line to read: "mR/hour at 85 cm was 43.5 percent of the ex-"

Page 696, 2nd column, last paragraph—add a period after word "layers" in 6th line. Delete last sentence.

Page 697, 1st column—delete rest of sentence continued from page 696.

Page 697, 2nd column, 1st line—correct spelling of word "planed" to "planned"



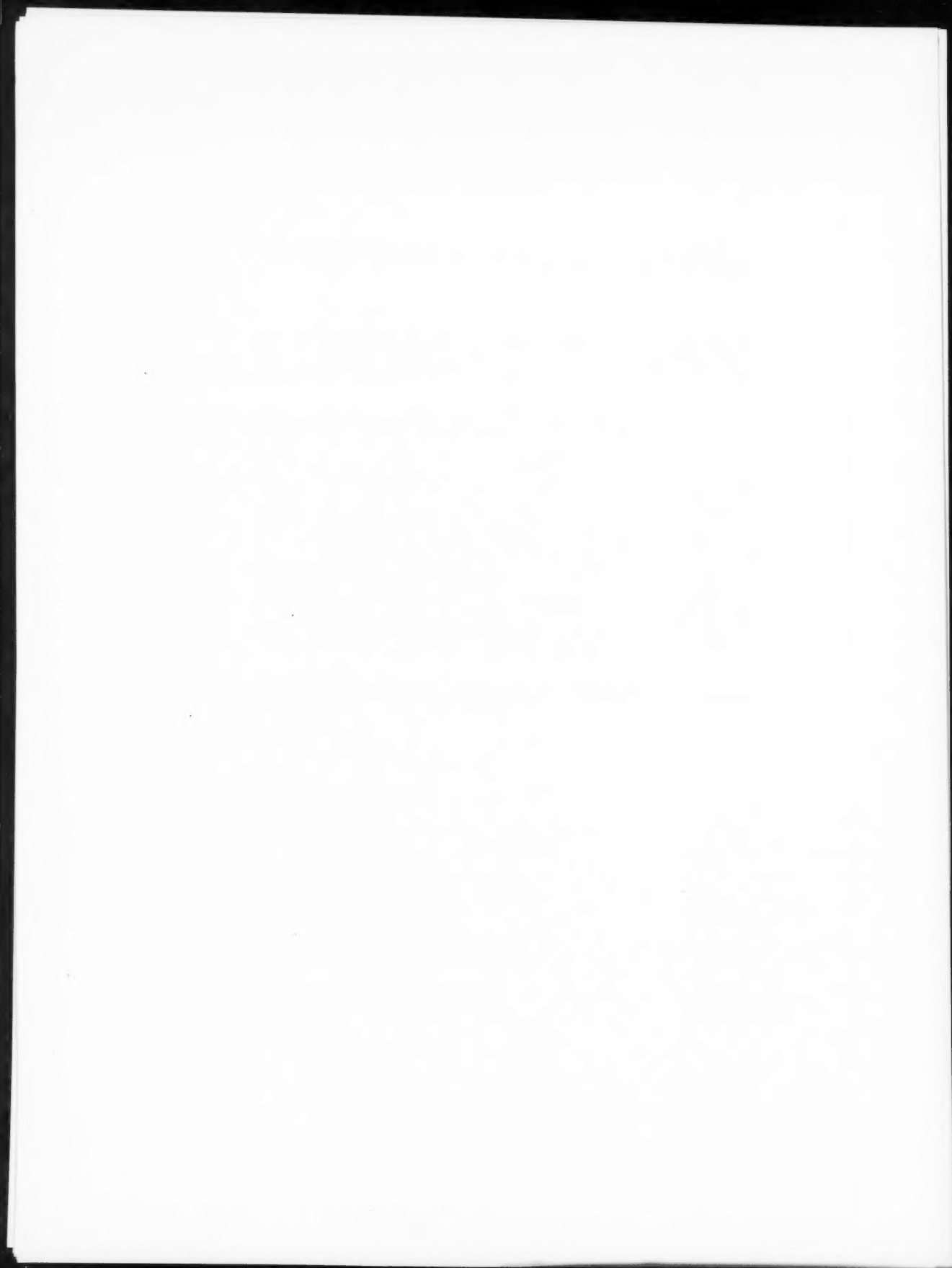
## SYNOPSIS

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

### COMPARISON OF ENVIRONMENTAL RADIOACTIVITY LEVELS AFTER FOREIGN NUCLEAR WEAPONS TESTS OF MAY 9, 1966, AND DECEMBER 27, 1966. *David R. Snavely and Warren A. Brill. Radiological Health Data and Reports, Vol. 9, February 1967, pp. 63-*

The environmental radioactivity levels following foreign nuclear weapons tests of May 9, 1966 and December 27, 1966 are compared, and the influence of dairy practices and weather conditions on levels of iodine-131 in milk are discussed. After the former test the highest monthly deposition by precipitation occurred in the mid-section of the United States south of the Great Lakes (576 nCi/m<sup>2</sup> at Jefferson City, Mo.) and in the northeastern section of Florida. The highest monthly deposition after the latter test occurred along the northern section of the west coast (2,545 nCi/m<sup>2</sup> at Portland, Ore.), northern Utah, the area west of Lake Michigan and in northern Vermont. Following the December test, the highest gross beta radioactivity of surface air particulates (119 pCi/m<sup>3</sup> at Las Vegas, Nev.), the highest gross beta deposition by precipitation and the highest contribution of nuclides belonging to volatile decay chains (including iodine-131), were found. The highest estimated cumulative iodine-131 intake from drinking 1 liter of milk per day (9,300 pCi/liter) occurred after the May test. This appeared to result from different dairying practices being used at the time of the two tests, and the more rapid elimination of iodine-131 from the cows' feed after the December test.

**KEYWORDS:** Beta radioactivity, fallout, iodine-131, milk, nuclear weapons tests, pasteurized milk network, pasture half-time, precipitation.



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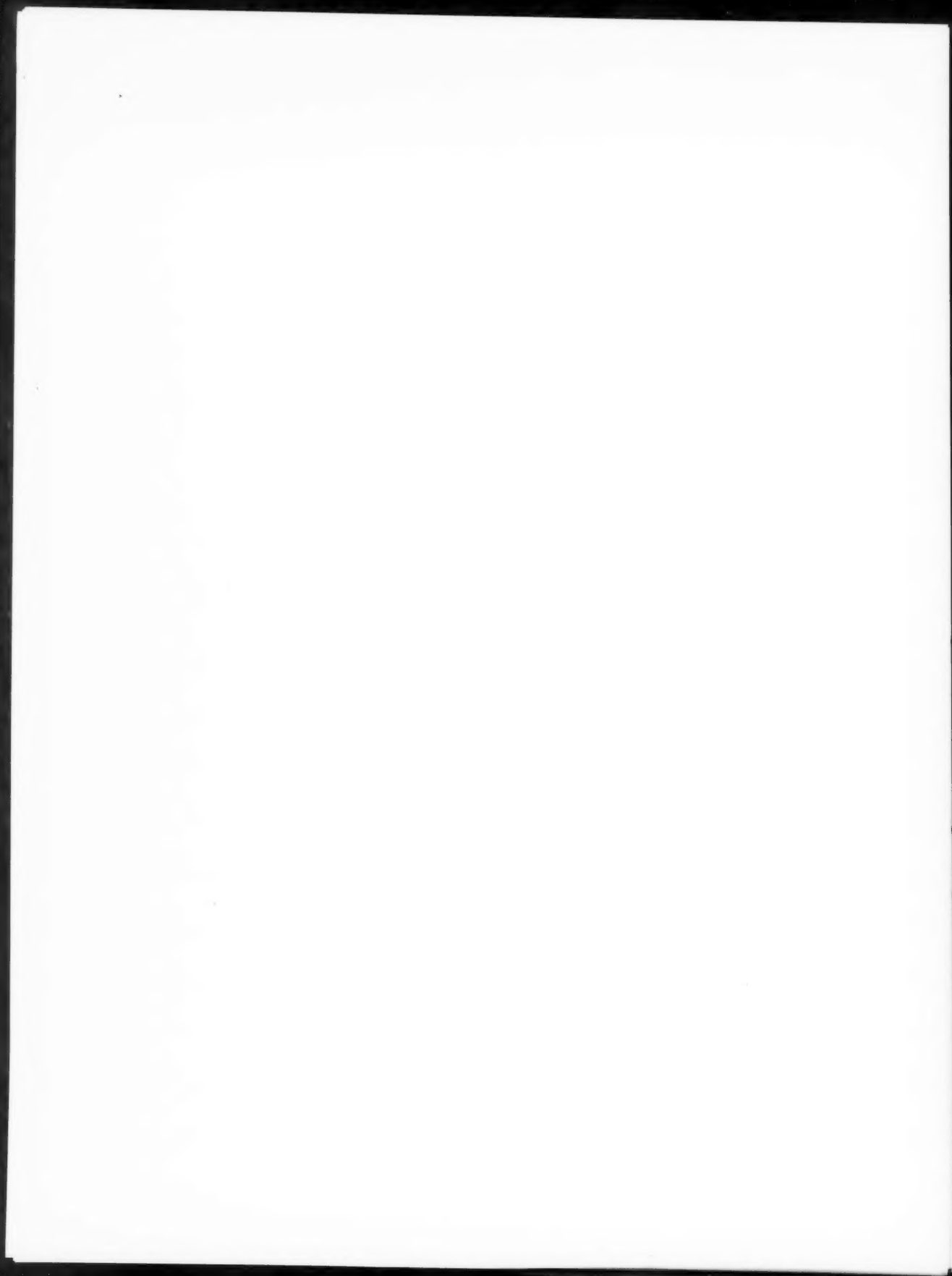
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February 1968



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